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Using PPGIS to Inventory Invasive Giant Hogweed in Latvia

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USING PPGIS TO INVENTORY
INVASIVE GIANT HOGWEED IN LATVIA

by

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Dedication

This thesis is dedicated to my father, Ron Larrivee, who has been supportive of me in all things and at all times. Love you, Pop.

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Abstract

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Giant Hogweed - a poisonous, invasive weed in Latvia - poses significant threat to biodiversity, and human health. This research develops a participatory GIS (PPGIS) program involving Latvian high school students as data collectors to monitor the geographic distribution of Giant Hogweed. This research explores challenges with implementing such a public program, how to maximize participation, and how participation impacts environmental awareness of participants. This research assesses accuracy of PPGIS-collected data, and how this impacts utilization of such data for classifying satellite imagery.

Results indicate that this PPGIS program is effective in facilitating data collection for monitoring Giant Hogweed in Latvia. Tested methods of increasing participation have proven largely unsuccessful to date. Statistical analyses of survey responses indicate participation had a marked effect on sensitivity towards environmental issues. Accuracy assessments indicate that quality of point data collected by participants is sufficient for use as ground verification, but not as actual ground truth.

Table of Contents

List of Tables

List of Figures

List of Plates

Introduction

Mankind has addressed the problems associated with invasive plant species throughout history. With recent explosions in globalization and vastly increased connectivity, there has been an equally explosive growth in the number and scope of invasive species across the globe, especially in the last 50 years (Nielsen, Ravn, Nentwig, & Wade, 2005). More than 50,000 species have been introduced to the vast open lands, lakes, rivers and coastal waterways of the United States alone, causing an estimated $137 billion in damage and lost agricultural revenue annually (Young, Schrader, Boykin, Caldwell, & Roemer, 2007). Invasions by non-native plants can have disastrous effects on human health and activity, and can in some circumstances have irreversible effects on the environment. A species left unchecked in an area with reduced or minimal competition and ideal growing conditions can permanently change the face of the landscape, leading to decreased biodiversity, ecological imbalance, and in some cases, the eradication of endemic plant and animal species (Young et al., 2007). Next to habitat loss, invasive species is considered to be the greatest threat to biodiversity (Olsen & Dinerstein, 1998). Some species, however, not only damage the landscape and negatively impact native ecosystems, they also pose a significant risk to human health. Giant Hogweed (*Heracleum sosnowskyi*) is such a species, and it is the most common of the three Giant Hogweed species found throughout Latvia.

The effects of *H. sosnowskyi* on humans and the environment are well documented. The Hogweed plant is poisonous to humans and can be fatal if ingested (Obolevica, 2008), but the primary need for control of the species arises from the toxic properties of Hogweed sap, and its negative health effects on humans and domestic animals. Hogweed sap contains naturally occurring compounds known as furocoumarins, which are toxins that cause phytophotodermatitis. The compounds - when they come into contact with human skin and are exposed to sunlight or another ultra-violet light source - cause painful burns, especially on the mucus membranes and areas where the skin in thinnest (Plate 1). Zhai and Maibach (2007) list dermatological effects caused by the furocoumarins found in Giant Hogweed as eurythema (a rash-like condition), vesiculations or bullae (blisters), increased skin temperature, and pruritis (acne-like pustules). Pysek, Jarosik, Mullerov, Pergl, and Wildl (2007), state that accounts of painful and persistent burns resulting in permanent scarring, disfigurement and blindness abound. Individuals working in agriculture, landscaping and other professions in which regular exposure to vegetation occurs are at high risk of being afflicted, as are children, who while playing have been known to use the large stalks of the plants (5 to 10cm in diameter) as spyglasses or peashooters (Klingenstein, 2008). Hundreds of injuries stemming from exposure to Giant Hogweed occur in Latvia every year (Klingenstein, 2008). Nielsen et al (2005), note that furocoumarins have also been shown in studies to be carcinogenic and teratogenic (known to cause birth defects in growing embryos), posing even further health risk.

Giant Hogweed also has a dramatic impact on the cultural landscape in Latvia. The traditional landscape of the region is characterized by a patchwork of forests, fields, and family farmsteads (Bunkse, 2000). As Giant Hogweed capitalizes on the ideal growing conditions it finds in these areas, the pastoral landscape with which many Latvians strongly identify themselves is significantly altered (Kabuce, 2006).

As discussed in The Site/Study Area section below, Giant Hogweed has been shown to have significant negative effects on biodiversity in Latvia (Kabuce, 2006). It quickly dominates native grasses, shrubs, and herbaceous vegetation, at times leading to near monoculture conditions (Neilsen et al., 2005). Some areas of Latvia with historically diverse and wide-ranging vegetative cover patterns have been reduced to massive stands of Giant Hogweed with only a few of the hardiest and adaptive native species remaining to scratch out an existence (Obolevica, 2008). Giant Hogweed's robust nature and resilience make it a potential threat to biodiversity in nearly every area that receives sufficient sunlight and water to support its growth (Obolevica, 2008).

This project builds upon prior research conducted in which PPGIS programs have been utilized to address issues of environmental quality (Luchette & Crawford, 2008), natural resource conservation (Anderson, Beazley, & Boxall, 2007), and the preservation of biodiversity (Kadoya, Ishii, Kikuchi, Suda, & Washitani, 2009). At the time of this writing, no instances have been identified wherein a PPGIS program was employed specifically to inventory an invasive plant species. Demonstrating the effectiveness of this type of data collection in addressing environmental issues is a goal of this research. PPGIS is a promising framework not only for increasing the volume of field data that can be collected for the purposes of this research, but also for increasing the level of awareness in the community of environmental problems that directly affect the population. It offers concerned scientists an opportunity to engage and educate the public, and it offers the various stakeholders among the Latvian public and private sector an avenue to become a part of the scientific process required to provide a solution to this significant problem.

Giant Hogweed

The Giant Hogweeds [*Heracleum mantegazzianum, Heracleum sosnowskyi (Plate 2), Heracleum pubescens*] are unusually tall, noxious, herbaceous weeds native to the Western Greater Caucasus area of Eurasia, between the Black and Caspian Seas, north to southwestern Russia, south to northeast Turkey, Iraq and Iran (Kabuce, 2006). *H.sosnowskyi* regularly reaches heights of 4 or 5 meters and can grow to heights exceeding 7 meters. Hogweed is the largest herbaceous broadleaf weed found in Latvia (Obolevica, 2008) and is readily able to shade out its competition. In addition to its great size, Giant Hogweed possesses a suite of unusual physical features that led to them being introduced as an ornamental curiosity to the botanical gardens of Europe beginning in the early nineteenth century. The first records of its appearance date to the year 1817 (Obolevica, 2008). The lower third of its stalk, which can grow to

Plate 2

more than 10 centimeters in diameter, supports deeply incised, dramatic leaves that can grow up to 1.5 meters across. These huge leaves and the shade they create help Giant Hogweed to decimate native plant populations and achieve a ground coverage rate upward of 80% in heavily affected areas.

Giant Hogweed has a number of characteristics that make them very successful invaders as well. The large, visually stunning flowering umbel appearing in its mature phase, can grow to 1 meter or more in diameter (ibid). This umbel is made up of hundreds of small bright white to light pink flowers that manufacture a tremendous number of seeds. Commonly, there are 20,000 seeds produced by each plant, with reports of up to 100,000 seeds on record (Nielsen et al., 2005). Current research indicates that approximately 90% of seeds produced are viable, and a small percentage of these (5% or less) remain in the seed bank for more than four years (Pysek, 2007). The great majority of these seeds - 90% - (Pysek et al., 2007) fall within a 4-meter radius of the parent plant. Nielsen et al. (2005) believe that conditions in northern areas such as Latvia, where frozen snow and ice cover are common, aid in the distribution of seeds to new sites, as they are able to slide across the surface propelled by wind. Obolevica (2008) indicates that even in these cold, northern climes, Giant Hogweed reaches full inflorescence, though earlier than in its native range.

Officially, *Heracleum sosnowskyii* is considered a monocarpic plant (it completes a single flowering cycle and then dies) but as many hybrids are said to exist between native and invasive Hogweed species, (Obolevica, 2008) the taxonomy of the plant and its close relatives in Latvia is in question, and requires additional study in order to be conclusive on this point. Indeed some European botanists claim that some species of Hogweed are only subspecies of *H. mantegazzianum*. Some reports indicate that a single Hogweed plant is capable of flowering for a period lasting anywhere from three to six years, though specific plants may possibly have been misidentified, in actuality being newly matured plants flowering for the first time (Neilsen et al., 2005).

Because of its great size, the Giant Hogweed and its close cousins *Heracleum persicum* and *Heracleum villosum* develop an extensive taproot to hold the above ground volume upright. Marrison and Goerig (2007) have speculated that the branched hogweed taproots are actually able to produce new and independent plants. Nielson et al. (2005) state that this taproot benefits the plant in a number of ways, making it freeze tolerant (up to -45^{o}F), increasing its regenerative ability, and allowing it to store large amounts of nitrogen below ground. Sufficient stores of nitrogen may allow the plant to complete its lifecycle (germination through seed production) in only two years. However, Pysek et al. (2007) report that studies show that the hogweed can remain in an immature or “rosette” stage for up to at least seven years under less than ideal, or stressed growing conditions. This ability allows the plant to slowly accumulate energy in its root stores until it reaches a level sufficient to produce full inflorescence. Rosette stage plants are easily overlooked, according to Klingenstein (2007), and a greater understanding of the plant’s lifecycle and persistence in this state would aid in improving eradication and control plans.

Its huge frame, broad, tightly spaced leaves, and dense growing pattern allow it to dominate open areas, quickly shading out native plants (Neilsen et al., 2005). Giant Hogweed stands are common along rivers and streams and can be particularly troublesome in these areas, as access (especially to machinery) is limited, and the water current provides a very effective transportation method for these seeds and often leads to new populations downstream (Neilsen et al., 2005). It cannot however, compete well in forests, as the canopy absorbs the bright sunlight upon which it depends for growth. Low-lying areas and areas with persistently saturated soils - such as Latvia's many upland bogs - are also unfavorable locations for Giant Hogweed invasions, as proper drainage is required for its growth.

Giant Hogweed prefers to take up residence along river and stream banks, as well as roadsides, ditches, power lines and other areas of human disturbance (Obolevica, 2008). Horticultural and crop scientists at Ohio State University David Marrison and David Goerig (2005) state that Giant Hogweed finds its preferred environment in rich, fertile, moist soils found along the fringes of agricultural areas (fence and tree lines), rural roadways, and especially in vacated farmlands and along stream banks. It finds ideal habitat in the well-drained, fertile soils of Latvia's vast tracts of vacant farmland (Marrison & Goerig, 2005). In fact, Giant Hogweed was intentionally introduced to Latvia in the 1940s (Pysek, 2007). It was planted in large farm collectives in the villages of Cesis and Madona by the former Soviet Union as a silage plant for livestock because of its hardiness and large biomass, and as a nectar plant due to its high natural sugar content, (Pysek, 2007). Plans to harvest Giant Hogweed were halted shortly thereafter because its anise-like scent affected the flavor of the meat and milk of the animals that ate it (Pysek, 2007). The Hogweed quickly spread out from areas in which it was cultivated and began to populate the surrounding countryside (Pysek, 2007).

Due to political changes (the dissolution of the U.S.S.R, and the period leading up to it) in the late 1980s and early 1990s, Latvia experienced a major shift in its economy that refocused its workforce from an agriculture base into a new, service-oriented economy. This shift left thousands of hectares of farmland unmanaged. The lack of human activity and management, combined with earlier improvements made to the land that increased drainage during active farming - nearly 85% of Latvia's low, fertile farmland has been improved for drainage – created an ideal environment for Giant Hogweed to proliferate. In fact it has - according to M. Obolevica of the Latvia University of Agriculture - become so widespread in Latvia that it has outstripped the government's current capacity to eradicate or even control the invader (Obolevica, 2008).

Giant Hogweeds are related to familiar vegetables such as the carrot and parsnip. Like these edible plants, Giant Hogweeds develop extensive taproots (Neilsen et al., 2005). This means Giant Hogweed can be very difficult to eliminate via mechanical methods like cutting or mowing. The stored energy allows the plant to grow back many times over, making conventional control methods expensive and time intensive (Kabuce, 2006).

Large Giant Hogweed populations also occur in other areas of the Baltics, as well as European and Siberian Russia, all of Eastern Europe north of the Balkans, France, Germany, the U.K., Scandinavia, Northern Italy, and the Benelux countries (Kabuce, 2006). Smaller, but in some cases increasing populations have also been recorded in the Northern U.S. (above the 40th parallel), and five provinces in Canada. Established populations are beginning to develop in coastal areas of Washington State and British Columbia, requiring the assembly of a bi-national committee to address the growing issue. Large-scale, international attempts at increasing understanding of the species and organizing control efforts have been developed, including The North European and Baltic Network on Invasive Alien Species, or NOBANIS (Kabuce, 2006), and the Hogweed Best Practice Manual (Neilsen et al., 2005), but to date, no comprehensive inventory of Giant Hogweed exists.

According to a 2001 survey, Hogweed had invaded and occupied over 12,000 hectares of land in Latvia (Obolevica, 2008). As a result of favorable conditions the plant has been able to expand its territory in heavy invaded areas at an annual increase of more than 10% (Obolevica, 2008). Many countries in Europe including the UK, Germany, France and all of Scandinavia are experiencing similar advances. In some studies involving heavily infested areas, Giant Hogweed has dominated nearly all native plant species, and greatly reduced overall biodiversity (Nielson et al., 2008). Although Giant Hogweed prefers to establish in vacant farmland and alongside roadways where seeds are deposited through human disturbance, it has also moved into and dominated the natural environments of some of Latvia's national parks. Along the banks of the rivers Gauja and Vaive in Gauja National Park, a heavy infestation of Hogweed accounts for 85% of all vegetation cover in some areas (Pysek et al., 2005). Gauja National Park houses 870 species of plant life, and though not all are associated with riparian systems, aggressive Giant Hogweed has displaced all but six native species in the most adversely affected areas (Pysek et al., 2005). The decrease in species diversity also leads to increase sediment load in the rivers, as the Giant Hogweed often die back to ground level in the winter. Studies also show a decrease in diversity of endemic fauna in these areas when compared to adjacent areas containing no invasive Giant Hogweed species (Pysek et al., 2005). Pysek et al. (2008) theorize that maintaining the integrity of these natural habitats will become increasingly difficult if the rate of invasion accelerates.

A number of methods used in the control and eradication of Giant Hogweed have been developed. A 40-month study was conducted between 2002 and 2005 in Europe to address the issue. This "Giant Alien Project" involved forty scientists from eight countries (including Latvia), and was initiated in order to develop a means of combating the Giant Hogweed problem throughout Europe. Regardless of the method, a comprehensive plan involving officials representing local, national, and international agencies needs to be in place in order to maximize effectiveness. The *Giant Hogweed Best Practice Manual* (Nielsen et al., 2005) suggests an *Integrated Weed Management Strategy* (IWMS). This approach involves the use of a combination of control methods following the development of accurate and up to date maps locating active stands of Giant Hogweed, and areas in danger of invasion. Mapping can be achieved in a number of ways, including ground survey, aerial photography and through the use of multi-spectral imagery. In theory, each plant has a unique spectral signature, and this signature can be used to locate stands or individuals of specific plant species. A project conducted by the University of California, Davis and the Maui Invasive Species Committee (MISC) in conjunction with the Nature Conservancy produced favorable results. Researchers were able to use spectral imagery to identify *Miconia calvescens*, an aggressive invasive species in Hawaii, to locate stands of the plant, even in dense jungle cover (Gradie & Myers, 1998). Given Giant Hogweed's need for sunlight, unique morphological characteristics and propensity for establishing in open areas and along riverbanks (Oblevacia, 2008), the prospect of using multi-spectral imaging technology to locate the plants appears promising.

Concerning the physical eradication of Giant Hogweed, Nielsen et al. (2005) have discovered several methods to have good effect, depending largely on local conditions (accessibility, density of growth) and available funding. Officially, the IWMS should "focus on optimal management with respect to efficacy, ecology and economy" (Nielsen et al., 2005, p. 20). In most cases, a combination of methods is recommended in order to achieve success. Chemical control appears to yield the best results in the reduction of Giant Hogweed populations. There are a number of drawbacks to the implementation of systemic herbicides, however. Glyphosate is legal for use in all affected European nations, but its negative effects on native plants and wildlife, soil and ground water are cause for concern, especially given Giant Hogweed's frequency along waterways. The European Union discourages and enforces strict control on the use of herbicides in such areas (Nielsen et al., 2005).

Other control methods include mechanical (mowing and plowing in open areas), manual (plant and root cutting, digging, umbel – flowers up to 2.5 feet in diameter – removal), and grazing. Nielsen et al. (2005) note that livestock are also susceptible to injury by contact with Giant Hogweed sap, and require daily monitoring. Regardless of which method or combination of methods is implemented, Klingenstein (2007) states that follow up monitoring and reapplication is required for up to seven years, until the local seed bank is completely depleted.

Though an organized offensive has been initiated with the goal of controlling, eradicating (where possible) and preventing the further spread of Giant Hogweed, much work remains to be done. An expanded public information campaign is essential in Latvia and abroad, according to Obolevica (2008). Through awareness, injury by accidental human contact with the plant and damage to livestock can be reduced, and local infestations can be identified and reported. Continued use of PPGIS and initiation of spectral imagery technology to expand comprehensive mapping of Giant Hogweed locations can only help to contain and reduce the presence of the invader. As well, further research into the morphology of Giant Hogweed as a species is necessary to improve the efficiency of implemented management plans.

PPGIS

The phrase "public participation geographic information systems" (PPGIS) originated in the 1990s within the planning community (Schlossberg & Wyss, 2007). PPGIS is an exciting, versatile and growing way for the public to engage in the environmental problems that face their community. Initially conceived as a platform to incorporate stakeholders in the decision-making aspects of the planning process, PPGIS has been expanded to include processes within a broad range of disciplines including community development, environmental justice, anthropology, archaeology, natural resource management, ecology, and biogeography (Weiner, Harris, & Craig, 2002). It is a tool for educating the public about local issues, and can be used to teach citizens about GPS & GIS technology (computer mapping and map data analysis) and allows the public to function as research partners in a broad range of projects. PPGIS is proving very effective as a tool in the monitoring of land cover changes, ecology and general environmental management. It efficiently merges the technical and scientific skills of researchers with the on-the-ground expertise of local citizens in the mapping process (Wang, Cinderby, & Forrester, 2008). It replaces the "professional-expert" model that excludes public input and frequently bears results that are impractical and not reflective of the needs of the local community (Schlossberg, 2002). Public participation often leads to improved results in spatial analysis, as a great deal more fieldwork is capable of being conducted when the public is recruited as research partners. It also offers an opportunity for stakeholders to take an active role in issues that affect them directly, and generally serves to increase local knowledge on environmental issue that affect the area (Kelly & Tuxen, 2003). The increased data collection potential and local knowledge provided to scientists are of great value, and often positively impact the outcome of their work. PPGIS is an adaptive and flexible platform capable of addressing a wide variety of issues, and a web-based map server is an ideal method for collecting such spatial data. This is not to say that PPGIS is without its drawbacks and problems. It can be difficult to engage the community in issues with which they are uninformed or disinterested (Anderson et al., 2009). Even as the world becomes more technologically connected, access to and knowledge of computer technology remains inconsistent. Uneven distribution of willing volunteers can lead to gaps in spatial data (Gouviea, 2004). Data quality is always an issue, as many PPGIS projects are still technical in nature, and require a level of scientific skill/knowledge that may not be present in the community. Local volunteers may be required to participate in a training program that ensures data is collected in a uniform and useable format (Wang et al., 2008).

This project incorporates a PPGIS program with a strong educational element. This aspect of the program will provide research partners with a foundational knowledge of GIS, remote sensing and GPS technologies (including the operation of a handheld GPS unit), as well as elements of biogeography, ecology, and plant physiology, including a detailed summary of Giant Hogweed. The health hazard posed by Giant Hogweed will be emphasized, and students will be required to pass a safety test and submit both a personal consent form and a parental consent form (if under age 18) prior to participation in data collection. Students will use a Garmin eTrex handheld GPS unit to collect data points in their area indicating the presence of Giant Hogweed, and upload that information to a spreadsheet stored on the site. Their contributions will be instantly viewable on a Google Maps[tm] map that is also incorporated into the website. Data from this map will be used in conjunction with satellite image analysis to map and model the spread of Giant Hogweed across Latvia.

We invite high school students – as well as any interested adults – to act as research partners in the collection of point data indicating the current locations of invasive Giant Hogweed in Latvia. The project is conducted through a website (http://sites.google.com/site/gianthogweedproject). The website is designed to provide detailed instruction on participants' roles as data collectors, and provides a platform for uploading collected data. The website educates participants about the processes and goals of the project, and includes them in the scientific process.

The site also includes a trio of surveys. The first will be completed as the participants begin the web-based training process. The results of this survey will establish a baseline for each participant's knowledge of Giant Hogweed and environmental issues. The second survey will contain the majority of the same questions as the first, and will be given to participants after they complete the full online training course. The answers from this will serve as metrics to illustrate any change in participant awareness of the problem of Giant Hogweed and broader understanding of environmental issues in general. The last survey will act as an arena for participating students to provide feedback regarding the organization of the program, and as an opportunity for participants to recommend schools or individuals that may be interested in joining the program. Results from this survey will be used to troubleshoot, streamline, and improve general quality as the project expands, and to determine the most effective approach to engage the public and improve participation.

On the same webpage, an alternative version of this survey is available for any Latvian residents who wish to participate in and/or provide their input about the project. This strategy is aimed at increasing participation in the data collection process, as well as providing a platform to educate the public about Giant Hogweed and how it impacts their environment. This PPGIS program is intended to be expandable to include many more students, as well as land managers, government agencies, park staff, farmers, and lay citizens with a willingness to become involved.

Remote Sensing

As remote sensing technologies continue to evolve and increase in power and capability, the practical applications for their use are rapidly expanding (Bradley & Mustard, 2006). Satellite sensors with spectral capabilities are effective tools for land cover analysis, and can present a clear picture of the composition, health and distribution of vegetation over broad areas (Bradley & Mustard, 2006). New, powerful hyperspectral sensors (AVIRIS, Hyperion) may be capable of accurately identifying specific plant species using the plants' unique "spectral signatures" (which may include their change in spectral signature associated with the plant phenology) to distinguish them from other species. As beneficial as these sensors are, there are drawbacks to the technology rendering it impractical in some scenarios (Underwood, Ustin, & Dipietro, 2008). The large number of bands – up to 224 – generates mountains of data that devour large volumes of storage, and can be too cumbersome to process and analyze in a useful way using currently available technology and methods. This can sometimes make use of these hyperspectral sensors impractical in large-scale applications. Further, the only available source of hyperspectral data in Latvia is Hyperion imagery at the 30m spatial scale. Given the frequent occurrence of Giant Hogweed in patches at or smaller than the size of a Hyperion pixel, this spatial resolution was deemed too coarse.

This research will utilize a time series of ASTER (15m resolution) satellite imagery to analyze the changes in distribution and rate of spread of Giant Hogweed throughout Latvia in recent years. Image classification will be performed for two images of the intensive study area: one near the beginning of the study period (~2000) and one near the end of the study period (~2010). Supervised, unsupervised and hybrid per-pixel classification methods will be implemented to obtain image classifications identifying Giant Hogweed throughout the intensive study area. The collected and to-be-collected ground truth data will be used for image training purposes and accuracy assessment.

Extensive ground-truthing and ground control data collection was conducted throughout the summer of 2010, and was added to fieldwork data collected by other researchers over the summer months of 2009. Sample pixels collected in the field will be used to train ERDAS Imagine software used to classify ASTER images to accurately indicate Giant Hogweed population distribution in the study area. A high rate of accuracy is expected for Giant Hogweed patches of sufficient size in the classification process due to the unique appearance of Giant Hogweed during full inflorescence. Images from the peak of the growing season (July/August) will be selected to take advantage of these conditions. Due to the easily distinguishable physiological characteristics of Giant Hogweed, it is expected that the multispectral ASTER platform will be sufficient to identify the weed.

Classified images will be used in other studies by the research team for development of predictive models indicating the possible spread of Giant Hogweed under various control scenarios.

The Site/Study Area

A long-term goal of this project is to develop a monitoring system identifying the locations of Giant Hogweed that incorporates all land area within the boundaries of Latvia. However, this research will identify an intensive study area to develop a monitoring system identifying the locations of Giant Hogweed using PPGIS and remote sensing. One of the benefits of this research is that the geographic range of study can be expanded once the protocols are put into place through this research. The intensive study site for the purposes of this research includes Gauja National Park, the town of Valmiera, Latvia, and some adjacent lands. **Gauja National Park** (Plate 3) is the largest park in Latvia encompassing 91,745 hectares, and lies northeast of the capital city of Riga. Gauja National Park is also Latvia's oldest national park, established while the country was still part of the former Soviet Union in 1973 (Kabuce, 2006). Gauja is a mixed-use park, with diverse leisure and recreational sites, nature reserves (from which most humans are barred from entering), some timber and natural resource harvesting, cultural landscape protection areas, and a number of human developments (Taff, 2005). Nearly half the park (47%) is forested, with the remaining land a mixture of natural and semi-natural open grassland, small agricultural plots and lakes and rivers (Taff, 2005). A number of rivers run though the park including the Vaive, and the Gauja, from which the park takes its name.

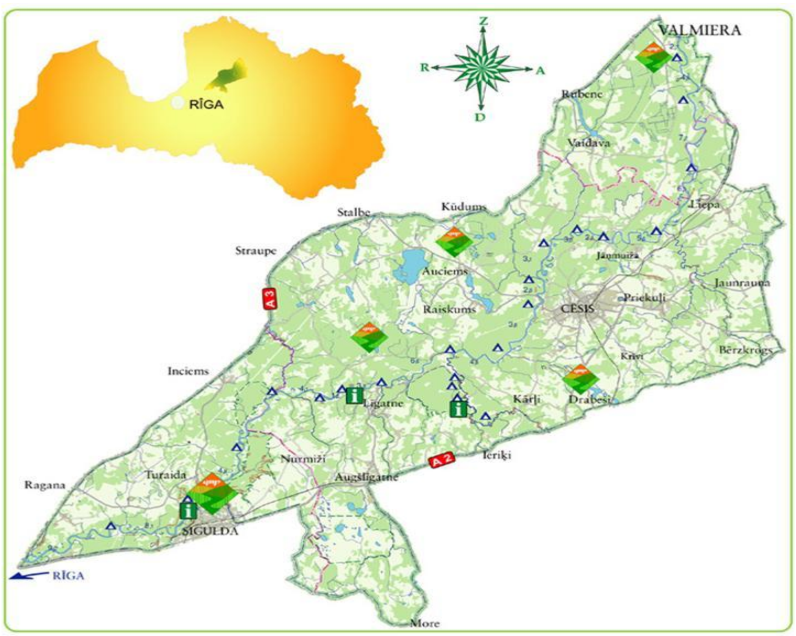

Plate 3

These rivers and open fields offer ideal conditions for Giant Hogweed to grow and flourish, which it has. As of 2001, an estimated 12,000 hectares of land in Latvia was occupied by Giant Hogweed (Obolevica, 2008). In some heavily infested areas within GNP, Giant Hogweed accounts for 85% of the vegetation

(Obolevica, 2008). In riparian environments like those found in GNP, this often leads to increased sediment loads in the rivers as Giant Hogweed dies back in winter, and does not retain the soil along stream banks (Pysek et al., 2005). GNP is a biodiversity hotspot in the Baltic region, containing more than 870 species of plants (Pysek et al., 2005). Giant Hogweed's effect on the ecology of GNP can be very clearly seen here, as some areas with dense growths of the invader contain only six remaining species of native flora. Decreases in indigenous fauna have been documented in these areas of GNP as well (ibid). Animals are forced out of these areas when the plant systems they depend on for survival disappear. Maintaining the natural integrity of GNP will become increasingly difficult with time unless the expansion of Giant Hogweed is not only halted, but reversed.

The city of **Valmiera, Latvia** (Plate 4), is home to just under 28,000 (2008) inhabitants and is located in the Vidzeme (Latvian for North) region of Latvia approximately 100km Northeast of the capital of Riga, and 50km South of the Estonian frontier. It also marks the Northeastern boundary of Gauja National Park, and sits on both banks of the Gauja River. The city is also significant to this research in that it is the home of Vidzeme University, a technical university that functions as a base of operations for fieldwork as well as the site for the beta testing of the PPGIS portion of this research. Invaluable resources, time, and energy were provided by the generous and diligent faculty, without which the development of this work would have been greatly impaired.

Plate 4

Though geographically small, (~18km^2), a number of significant infestations of Giant Hogweed exist here. Also present are secondary, rosette stage growth and areas managed (mechanically mowed/controlled) by the local government. This diverse range of environments makes Valmiera an ideal study site.

Research Questions/Hypotheses

1a. How can a PPGIS system be developed for Latvian high school students and other interested parties to help monitor and eventually control Giant Hogweed, and also receive important relevant education in the process?

A web-based format will provide the ideal environment in which all aspects of the PPGIS program can be housed. Training modules for the academic portion, detailed instructions for fieldwork, and spreadsheets and maps for GPS data upload can all be included in one easily accessible location. Google Sites provides a simple but adequate format that requires minimal programming knowledge facilitating site development, and ease of use for program participants.

1b. How did/will the relationship between the researchers and the PPGIS participants help redefine the research goals?

It is anticipated during the development of this PPGIS program that the same local expertise provided by active participants in the data collection program could potentially redefine minor aspects of the direction of this research. The same holds true for interactions with staff from Vidzeme University and other officials with whom it is necessary to interact in the interests of seeing the project through to fruition. The input of these individuals may possibly shift the focus or bring about a shift in the allocation of time in resources from within the various aspects of the research as it moves forward.

2a. How can participation in this program be maximized?

Involvement in the program will be maximized through a “grass roots”, bottom up approach. Participants in the beta test for the program conducted in August 2010 will act as ambassadors to their respective schools distributed throughout Latvia. They will bring their experience and what they have learned home with them, and the program will be incorporated into the science curriculum at their schools. These initial schools will act as spreading centers, and the attention generated by their activity will spread the program to schools in other areas. In addition, a number of media outlets will be approached in an attempt to increase the visibility of this project.

2b. What challenges are involved in utilizing the public for the collection of data in the effort to monitor Giant Hogweed in Latvia?

As indicated by an in depth literature review conducted prior to beginning the development of this program, a number of thematic disadvantages are expected. With any PPGIS program wherein the public is enlisted to contribute to the data collection process, a degree of inaccuracy in the reporting of the field data that collected is expected. Some level of non-compliance with the protocol established for the program may be experienced. As the site is located in a foreign country where English is not an official language, the potential for language barriers to inhibit the progress of the program exists.

3. What are current levels of awareness of high school students regarding Giant Hogweed and other environmental issues, and how will participation in this program affect their awareness of these topics?

A goal of this research is to create a heightened sense of connection in this PPGIS program's participants to the local landscape, and to increase awareness of environmental problems. Environmental awareness in participants may be increased by incorporating broad scientific lecture material and materials tailored specifically to the problem of Giant Hogweed in Latvia. The overall design is intended not only to increase or develop knowledge of the problem of Giant Hogweed in Latvia, but also to tie the local problem in to the larger problem of invasive species and the mélange of other environmental issues that threaten the health of the world's ecosystems. Statistical analysis of survey questions answered by participants before and after working in this program may produce insight into whether their participation has had an impact on their view of environmental problems, as well as their perception of the environment.

4. Based on the collected PPGIS data accuracy, what specific methods can be used to integrate data obtained from the PPGIS project involving Latvian high school students and other interested parties with data obtained from remote sensing/satellite imagery for locating Giant Hogweed?

Data for Giant Hogweed locations collected by various research partners will be integrated in the future with classified satellite imagery to create a more complete distribution and inventory map of Giant Hogweed in Latvia. Testing the accuracy of data collected by participants in the field through verification by high-resolution aerial photographs and GPS data collection by the research team will provide insight into the level of usefulness of the data in image processing. Some level of error may exist in collected data due to user error and/or compliance issues.

Methods

1a. How can a PPGIS system be developed for Latvian high school students and other interested parties to help monitor and eventually control Giant Hogweed, and also receive important relevant education in the process?

In order for Latvian high school students to become involved in the monitoring of Giant Hogweed, a framework in which data can be collected, uploaded, stored and analyzed had to be developed. As the study site is many thousands of miles removed from the base of operations and the project is intended to function without the direct oversight of the research team, a web-based GIS format was the ideal choice. Even without this consideration, the ease with which data can be uploaded and collected in this format makes it far superior to any other available method. This format also allows access to information about the project and the dangers of Giant Hogweed, instructions on how to participate and properly submit data, training for an academic element, surveys, a news forum, and photo gallery.

Google Sites^{tm} provides a simple, easy to use format that is capable of performing the intended function of this project, and easily incorporates the tools required to see it to fruition. The development of a test website found that Google Maps^{tm} (to display geographic data), Google Docs^{tm} (for surveys, and to upload GPS input), and Google Spreadsheets^{tm} (for GPS input and survey response storage), as well as MS PowerPoint^{tm} presentations (for the educational component) could be easily integrated within the website, and the site could be organized in an easy to understand, logical progression to help each participant through the project from start to finish.

In order to proof the program and determine its feasibility, a beta test was required. Following a successful beta test, networking with participants was necessary – primarily through electronic means – in order to maintain continuity and to move the project forward.

1b. How did/will the relationship between the researchers and the PPGIS participants help redefine the research goals?

An additional page was created when considering how the project website could be used as a means of collecting data regarding participant's opinions of both the functionality of the program, and its goals. A brief survey was created where participants are able to rate their experience with the program. There is also an opportunity to suggest improvements in the functional/mechanical aspects of the website, and to express whether they felt any aspect of the program seemed unnecessary or if anything should be added. Space is provided to tell us how they feel about the goals of the project, and what possible ways its impact can be maximized.

Informal interviews were conducted with the various individuals the research team came into contact with in the process of achieving project goals throughout the summer of 2010. Government officials tasked with the control/eradication of Giant Hogweed, faculty, staff and students at Vidzeme University and the University of Latvia in Riga, land owners who have Giant Hogweed on their property, and members of the media were informed of the mechanics and goals of this research and through direct verbal communication, offered the opportunity to express their opinions about Giant Hogweed, what can be done about it, and what sort of impact they feel our work might have in addressing the problem.

During the beta test, students were asked how they would combat Giant Hogweed in Latvia. Students were divided into four groups and told that they are applying for a government position in which each group will be responsible for the control and eradication of Giant Hogweed in Latvia. They were given no rules or restrictions, and were informed that the group with the best proposal (judged by the research team) would be awarded the position. This exercise was designed both to allow the students to think critically, and to use problem solving skills relevant to the environmental issues. This exercise also functioned as an opportunity for young Latvians who have local knowledge and are directly affected by the issue to offer insight about the problem of Giant Hogweed in Latvia.

2a. How can participation in this program be maximized?

In an attempt to gather information from those who have already completed their work as research partners in this project, a survey which participants are able to complete on a voluntary basis after collecting and uploading data was added to the project website. This survey is aimed at improving the function of the PPGIS program, focusing on accessibility, ease of use, and optimizing the engagement of research partners. Questions are opinion oriented (qualitative), allowing participants to express their opinions of the overall quality and functionality of the program/site. Space is also provided wherein partners have the opportunity to suggest in their own words how they feel the program could be improved. The last question in the survey is geared towards making use of the social connections of participants, where they can suggest other parties and/or institutions that may be interested in participating in the program.

In addition to attempts to utilize the social capital of those who have already participated in the program through the survey, media exposure was desired as a means of attracting individuals from all across Latvia who likely had no prior knowledge of the project. Various newspapers, magazines and radio outlets were investigated as possible sources of increased visibility for the research.

2b. What challenges are involved in utilizing the public for the collection of data in the effort to monitor Giant Hogweed in Latvia?

Methodology for determining what sort of problems were/are associated with this project involved a combination of literature review and in situ experience. – The literature review consisted primarily of literature regarding PPGIS projects in which the public acts as a data collecting entity (Anderson, 2009; Gouveia et al., 2003; Kadoya et al., 2009; Kelly & Tuxen, 2009; Wang et al., 2007). Problems were addressed as they arose throughout the beta testing process, as well as in the period following the beta test up to the time of this writing.

3. What are current levels of awareness of high school students regarding Giant Hogweed and other environmental issues, and how will participation in this program affect their awareness of these topics?

A pair of surveys developed for this project designed to determine participant knowledge and opinions regarding the presence of Giant Hogweed in Latvia also contain questions intended to gauge participant awareness of environmental issues on multiple scales. The same or similar questions (i.e.:

How important are environmental issues to you? What are the three greatest threats to the environment in Latvia/to the planet?) were asked before the training, data collection, and GPS input stages are completed and again after these steps are completed in two separate surveys in an attempt to assess any changes in the environmental awareness of participants. Answers are collected through Google Spreadsheets[tm] imbedded in the website and prepared for analysis. The analysis consists of calculating the difference in scores/responses for each survey question, and then tabulating descriptive statistics among participants for each question. Cross-tabulations and chi-square tests were used to test associations between 1) improvements found on specific test questions, and 2) other descriptive statistics about the study population (e.g., age, sex, initial score/response on some test questions). A descriptive summary of key findings can be found in the **Results** section**.**

4. Based on the collected PPGIS data accuracy, what specific methods can be used to integrate data obtained from the PPGIS project involving Latvian high school students and other interested parties with data obtained from remote sensing/satellite imagery for locating Giant Hogweed?

Determining Accuracy

The accuracy of point data for Giant Hogweed locations collected by Latvian high school students was assessed by comparing participant collected data to point data collected by the research team, and through verification by aerial photography obtained in Google Maps[tm]. Point data of Giant Hogweed locations collected in the field by the research team were recorded with a Trimble

Juno GPS unit, a much more powerful instrument than the Garmin eTrex H GPS unit used by PPGIS participants. With the Trimble, we took approximately 120 readings from each point location. These locations were then averaged to obtain a highly accurate data point for each location. The points were then differentially corrected in GPS Pathfinder Office to achieve still greater accuracy.

Data Integration

While this thesis does not attempt to actually integrate the data collected by PPGIS participants (Latvian high school students), it will discuss *how* it can be integrated now that the quality of the data has been assessed.

The collected data will be integrated during image classification for mapping and modeling processes. It may be used as ground truth/verification. This application requires locating the participant's estimated point on a high-resolution aerial image and verifying the presence of Giant Hogweed. Once presence (or absence) of Giant Hogweed has been verified, the center of the patch can be identified, or a polygon defining the extent of the patch (vector tracing) can be created.

For Giant Hogweed spread modeling, it may be sufficient to use approximate points instead of exact coordinates of Giant Hogweed. For this purpose, this tedious verification process may not be necessary.

In satellite image classification, a presence/absence classification scheme will be created for locations of Giant Hogweed. Each pixel will be considered as either containing Giant Hogweed, or not containing Giant Hogweed. Point data collected by PPGIS participants will be converted to pixels for modeling purposes, but could also be maintained as a vector data set, so attributes (presence/absence, number of Giant Hogweed, collected by participant/research team) may be stored.

Results

1a. How can a PPGIS system be developed for Latvian high school students and other interested parties to help monitor and eventually control Giant Hogweed, and also receive important relevant education in the process?

In the development of a web-based GIS program in which high school students are able to act as research partners, this system proved successful. The beta test – discussed in greater detail later in this section - conducted in Valmiera, Latvia in August of 2010 proved that the website functions as a tool capable of communicating the goals and purpose of this research, the role of participants within it, providing educational materials to those participants, and as an effective means of collecting and storing point data to be used in analysis. To date, 44 Giant Hogweed locations from three separate regions of Latvia have been uploaded, displayed, and stored on the website. Statistical analysis indicates that the program has also had impact on student participant's environmental awareness and provided them with knowledge regarding the impact of Giant Hogweed (discussed further in **Results: Research Question 3**). The bottom up approach of utilizing beta test participants as ambassadors to their high schools to expand the program has proven ineffective; the program has not yet been integrated into the science curriculum of any Latvian high schools to date (see **Results: Research Question 2a** for further remarks) – however, three participants have supplied additional data since the conclusion of the beta test, and more plan to do so later in the spring of 2011.

The following sections are an outline of the creation of the various components of the project website - including a detailed description of their respective purpose and function within the PPGIS program – the testing phase of the program, and the development of the related materials required to move the program into the next phase.

Public Interface/Website

As the implementation of and participation in PPGIS programs of various foci continue to grow, so does the use of project websites as a means of interacting with the public. It is difficult to imagine a more efficient and effective way of reaching a broad spectrum of the public in a study area so far removed from the base of operations. However, as with any other form of communication in participatory science exercises, internet-based programs have their drawbacks. Though it is true that the world is connected through the Internet, not everyone – even in 2010 - has access to the technology. Availability and rates of usage can vary considerably from location to location, but it is likely in a computer-dependent framework that a portion of the population will be unintentionally excluded. For this particular study area, access to public and private internet-capable computers is high (all public libraries in Latvia have internet ready computers available to citizens), and access for the target population of high school students is excellent (most schools have internet in the classroom, or a computer lab). Given these considerations, plans were made to construct a website for the project.

In order to achieve the goals of this project, and to provide a simple, user-friendly interface for participants to reliably upload data, it was necessary to construct a site that is both comprehensive and easy to use. The intent is to have all materials required to participate in the project except for the actual field tools (hand-held GPS unit, compass and field book) accessible from a single location.

In addition to considering the content of the website, programming knowledge among the members of the research team is not extensive, so it was practical to seek a platform that requires slightly less technical website building and programming skills. Google Sites™ provides a simple, efficient website framework that suits the current needs of this project. In addition, other Google products (Maps, Docs, Spreadsheets) are extremely easy to incorporate, and fulfill all of the various functions within the framework of the website. The function of each of these elements will be discussed later in this section.

Translation

Translation of the site was required, since though English is spoken by many in Latvia, it is at best the target population's second language. Often it is third, after Latvian and Russian, if it is spoken at all. Due to time constraints, translation was not completed before conducting a beta test in August, but all of the beta test (discussed later in this section) subjects were proficient in reading and writing in English. A reliable Latvian translator was located in summer of 2010, and translation of the entire site along with the educational modules (discussed later in this section) was completed in September 2010. Plans to translate the site into Russian - as Latvia has a considerable number (~1,000,000) of native Russian speakers as well – are in development.

Content

Since the website is public, and open to all interested persons, a **Welcome Page** in both Latvian and English was created to initiate visitors to the site with a broad overview of the project. Following the Welcome Page, participants are asked to complete a brief **Introductory Survey**. This survey contains carefully developed metrics that are designed to assess any effect participation in the project might have on environmental awareness. It is used in conjunction with an **Outgoing Survey**, which is filled out by participants upon completion of the data collection/upload portion of the project. These surveys are discussed in depth in the Methods section for Research Question 3.

An information page with general information **About Giant Hogweed** including physiology, human health dangers, history and current distribution in Latvia follows. Students then proceed through the program (**Online Course for Student Partners)** in a simple and logical manner clearly laid out in the website sidebar. This page includes instructions that outline how students are to proceed through the program. They are able to access the **"Training Modules"** at this point, which consist of three MS Power Point slideshows. This is a comprehensive online course which is reviewed by students in order to study for the **Giant Hogweed Safety Test** (developed by this research team) to be administered by teachers in participating schools, and which must be passed before they are allowed to conduct fieldwork.

These **Training Modules** are divided into three sections:

1. Mission: Eliminate the Giant Hogweed
2. Giant Hogweed
3. GPS

The first section **(Mission: Eliminate the Giant Hogweed)** is designed to present an overview of why this research is being conducted, what the goal and output of the research is, and exactly how – step by step – the program is performed. It also clearly delineates the role of students/participants, and alerts them to the critical nature of their work.

The second section provides a physiological overview of the target species **(Giant Hogweed)** including life cycle, reproduction, distribution, historical information on where it comes from and how it got to Latvia, health hazards, ecological impact, control methods, and an in depth review of how to identify Giant Hogweed in every stage of its lifecycle. This last portion of the module is especially important. Giant Hogweed poses a significant human health risk, and it is critical that participants are able to confidently and accurately identify Giant Hogweed in the field to prevent serious injuries. The ability to identify Giant Hogweed and distinguish it from other plants – especially early in its lifecycle – will also help to maintain a high level of accuracy in the reporting process.

The third section explains the mechanics and function of **(GPS)** technology. A brief overview of how satellites interact with receivers on the ground and what we do with the information provided by this system, prepares participants for the instructional section on the use of the Garmin eTrex GPS unit found in the next section of the website.

It should be noted at this point that the content of the **Training Modules** as well as the **Giant Hogweed Safety Test** was developed by another member of the research team (Rebecca Almond, MS candidate in Earth Sciences, University of Memphis) for use in this project.

Instructions

Instructions for the use of the GPS and fieldwork tools, and the proper way to upload collected data are also included, and the pages containing this information are found in the next step on the website. The instructional section of the website consists of the following pages:

Checklist

Caution!!!

Using the Garmin eTrex GPS Unit

Using a Compass to Take a Bearing

Using your Field Book

Adding Your Data to the Map

The **Checklist** page serves as a review for participating students. It helps to insure that no students/individuals move into the data collection stage of the project without first completing the necessary training, passing the Giant Hogweed safety test, and completing the necessary and appropriate **Consent Forms** (discussed later in this section).

Caution!!! is a final reiteration of the human health risk posed by Giant Hogweed. It is a last chance to remind participants to never touch or come near the Giant Hogweed before they begin their data collection in the field.

Using the Garmin eTrex GPS Unit gives students a fundamental understanding of how the hand-held GPS unit selected for this project operates, and how to use it in conjunction with the compass and field book (discussed later in this section) to properly collect data in the field. Basic functions including powering the unit on and off, saving waypoints (Giant Hogweed locations), deleting waypoints, and checking satellite accuracy, as well as important setting information such as language selection and coordinate requirements are discussed. It was discovered that converting the unit to provide point data in a decimal degrees format avoids any mapping issues in Google Maps. For this reason, this section of the page receives special stress when conveying information to students, including a number of examples.

Using a Compass to Take a Bearing assumes that students have no orienteering knowledge. It provides a basic foundation regarding function of the compass provided by the program, what a bearing is, how to take a bearing, and why this information is necessary. As it may not be immediately apparent that the point data provided gives the location of the operator and not the location and direction of the Giant Hogweed relative to their position, the importance of this information is stressed here. Students are also instructed here to estimate the distance (in meters) to the center of the patch of Giant Hogweed, and to record their estimate along with the bearing (in degrees) in their field book.

Using your Field Book is a simple form to help guide students through the process of recording their fieldwork in a format that helps to reduce errors and ensure it will be useable at a later date in image classification. Included here is a brief description of each category and how the information will be used. An illustrated example can be viewed on this page as well.

Adding Your Data to the Map prompts students to move on to the **GPS Input** page, and alerts them that the data collection phase of their work has been completed. This page also shows students that their work will be viewable on the map as soon as it is added.

GPS Input (Data Entry)

This page is the location where participants upload their field data. A simple script (written by my colleague Simon Fonji, PhD candidate in Earth Sciences, University of Memphis) connects a Google form embedded on this page to a Google map also found on this page, allowing their data to be instantly viewable. These data are saved via the form in a Google spreadsheet that can be easily accessed by members of the research team, and leaves the coordinates in an easily accessible and well-organized format for later use in image analysis, mapping and modeling. The project website can be viewed at: sites.google.com/site/gianthogweedproject.

Consent Forms

All consent forms required for participation are available here in both an online-electronic, and printable format. The completed consent forms are also recorded and collected in Google spreadsheets. Because this project utilizes human subjects in the capacity of research partners, and because Giant Hogweed poses a human health risk, this project was submitted to and passed Internal Review Board – Human Subject Research Approval, developed by Dr. Taff with the help of the research team and submitted by Dr. Taff. The approved use of human subjects is contingent upon each participant electronically signing a consent form stating that each participant is aware of the dangers associated with working in close proximity to Giant Hogweed. In addition to this, teachers at participating schools with students under the age of eighteen are instructed to maintain a paper copy of signed consent forms. Further, the high school teachers themselves are also required to submit an online consent form to have their class participate in this research.

Products/ Field Work Tools

In order to carry out the fieldwork associated with this project, specific tools are required. As stated before, participants act as research partners by collecting data on the specific locations of Giant Hogweed. For this data to be useful to the project, maximizing accuracy of reporting and reducing opportunity for reporting errors is necessary. It was determined that the basic tools needed to accomplish this goal included a GPS unit capable of storing multiple points in decimal format, a compass (to establish bearing from the perspective of the participant to the center of the patch of Giant Hogweed) and a field book to record data regarding the size of the patch, distance to the patch from the point of observation, as well as any relevant notes the participant might want to add. A protocol regarding how the data is recorded needed to be established. Decimal format for latitude and longitude coordinates was chosen with the intent of reducing errors in the data uploading process because it is the format most easily read by the Google Maps application used to upload collected data.

The compasses and field books suitable to the needs of the project were acquired for just a few dollars per unit. GPS units with sufficient accuracy for the project's goals were acquired for $100 each, as discussed below. As this is a pilot project to test processes for carrying out this work across the entire country of Latvia, utilizing an inexpensive GPS is essential, as many GPS units (~200) will be needed in order for all the high schools in the country to be able to participate. Like many scientific research endeavors, this project operates under a modest budget, so expensive units were out of the question. Exhaustive research into the range of products available returned a small number of perspective candidates, with the final decision being made to purchase a small number of Garmin eTrex H model handheld GPS units for the initial stages of the project. This product has the combination of accuracy (to 3m), durability, ease of use and affordability that fit the needs of this project.

Teacher Instructions

Incorporating PPGIS into academic curriculum depends, of course, on the involvement of educators. In order to introduce the project and its goals, and to clearly outline their roles as intermediaries, an "electronic information packet" for teachers at participating schools was developed. The packet contains a brief overview as well as instructions for the implementation of the academic portion of the program, and clearly outlines the role of educators in the project. It includes the test students are required to pass before conducting fieldwork (which includes a safety section), and the test answers. As such, the packet is emailed directly to educators involved in the project, and not made available on the site. It is designed to be small enough to send as an attachment in an email, and presented in simple terms. To avoid software issues, it is available in both .doc and .pdf formats. These instructions were also translated into Latvian. In addition, plans to have it translated into Russian are underway.

Beta Test

Target Participant Population: High School Students. Early in its development, the decision was made to incorporate a strong educational component into the framework of this project. Educated citizens tend to make better decisions, and can carry a multiplier effect as those that participate share the knowledge they gain with their community. Although the project is open to any individual of legal adult age in the study area that has a desire to participate, student populations are ideal as schools have the potential to be spreading centers, and are generally - and through necessity - evenly distributed across the landscape, increasing the chance for more comprehensive coverage. The Baltic International Summer School (BISS) from 1 - 4 August, 2010 presented a unique opportunity to beta test this project, in that a group of students from schools all over Latvia would be gathered in Valmiera, Latvia for four days of study. This program held the advantage of allowing for controlled testing of the educational component, practical fieldwork, and data upload processes. The hope stemming from this experience was that students would then act as ambassadors for their schools when they returned home for the regular school year, and promote cooperation of their high school geography and biology classes and teachers in this project.

In preparation for the beta test, a graduate student from the Department of Earth Sciences at the University of Memphis who is not attached to this research project was recruited to perform a dry run of the program. Minor adjustments were made to the instructions for fieldwork, but no major reworking was required. Dummy points located on the University of Memphis campus were substituted for Giant Hogweed locations. The test subject collected these points and uploaded them to the form on the GPS input page of the project website. With little oversight, the test subject was able to complete each portion of the program and successfully upload data via the project website. Data transfer from the spreadsheet to the embedded map was successful, and data was transferred from the spreadsheet form to the archived spreadsheet in the desired format. All other interactive aspects of the website (survey forms, hyperlinks, photo gallery, etc) performed their intended functions.

1b. How did/will this relationship redefine the research goals?

Interaction with student participants, staff and faculty at Vidzeme University in Valmiera, as well as members of the scientific community such as Maris Laivins from the University of Latvia, and government officials (Inese Margevica and Gunita Skupele of the Latvia Plant Protection Agency), has proven to be insightful but not surprising in regard to the level of knowledge Latvians possess concerning the problem of invasive Giant Hogweed in Latvia.

Though some lack of knowledge was encountered in the introductory survey filled out by beta test participants, the majority of students the research team worked with in summer of 2010 are well aware of Giant Hogweed and the health and environmental problems it poses. The most common response from beta test participants (given during a class exercise in the academic portion of the program) as to what prohibits Giant Hogweed from being brought more quickly under control is a lack of government resources and funds. These responses have provided reinforcement for this research and caused little adjustment to the original research objectives.

2a. How can participation in this program be maximized?

The survey page **Please Tell us What You Think of Our Program**, which was created with the intent of capitalizing on the social networks of participants is a voluntary aspect of the program. This bottom-up approach of utilizing beta test participants as ambassadors has been ineffective. At the time of this writing only one response has been collected from this page, and no referrals for other schools or individuals have been made. Additionally, the program has not yet been integrated into the science curriculum of any Latvian high schools. Positively, three participants have supplied additional data since the conclusion of the beta test, and two more plan to do so later in the spring of 2011.

Some success was found in the research team's work to persuade various media outlets to cover this research. Ieva Pukite writing for ***Ir*** magazine - a national news and culture magazine distributed throughout Latvia - produced a five page feature outlining the work and goals of this research. She spent a number of days in the field as an observer (including parts of the beta test), attended meetings, and recorded interviews with each member of this research team. According to its website, ***Ir*** magazine has a monthly circulation of ~100,000 copies.

Janis Rozitis of ***Radio Kas Te Ir -*** a commercial radio station broadcast throughout Latvia and to parts of Estonia and Lithuania - also agreed to a live, one-hour radio interview with the author. At the time of this writing, the approximate listenership of ***Radio Kas Te Ir*** has not been determined.

A short film project supported by Vidzeme Augtskola and directed by Professor Emeritus Lucille Rhodes documents the beta testing aspect of this research, and features an outline of work that has been accomplished thus far, and what the project hopes to eventually accomplish. The 12:08 length film is available to be viewed on YouTube at:

http://www.youtube.com/watch?v=Nb8htP-11QU

At the time of this writing the video has been viewed ~200 times.

2b. What challenges are involved in utilizing the public for the collection of data in the effort to monitor Giant Hogweed in Latvia?

Lack of participation/data. A number of obstacles restricting the flow of progress of the project have emerged in the period following beta testing. Communication with teachers at schools who student beta test participants were able to convince to volunteer to participate in the project has been very limited. Six students who participated in the beta test volunteered at the conclusion of testing to work with a science teacher at their hometown school to initiate the program at their school. Preliminary communication occurred while students were still convened at the beta test site in Valmiera, Latvia. At the time of their departure, students from four of these six “pilot” schools had secured support for the program with their teachers. A series of follow-up emails were sent, and were intended to establish the first direct contact between the research team and prospective science teachers and determine a plan for administration of the educational component of the program. These emails met with little response. One teacher has responded and submitted the online consent form. Her students are one of two groups of participants to date to have added any additional (occurring since the beta test in Valmiera) field data to the map, however the only students that added data were those involved with the beta test. A workshop in the summer of 2011 to train and inform Latvian high school science teachers about the project specifics is in planning stages at the time of this writing.

Language. The Latvian/English language barrier has represented an obstacle in the forward progress of the project. Although the website is available in Latvian, a significant amount of personal correspondence is required between University of Memphis researchers and teachers as participating schools. It is unclear to what extent language has impacted the level of communication, but very little communication has actually occurred.

Distance. Distance from base of operations and the study area has been an issue. The research team only had funds to provide four GPS units to four high schools at the end of the BISS session/beta test. Students from six high schools wished to have further involvement in the project. Shipping additional units from Memphis to Latvia to remedy this issue has proven to be cost prohibitive.

One volunteer student has reported Internet access issues that prevent the opening of the project website on school computers. Steps are currently being taken to circumvent this issue, but the lack of accessibility and restriction on what type of web-pages may be viewed from school-owned computers is likely to reduce participation, and may exclude the possibility of including the educational and coursework components of the program from being integrated into some science curriculum as intended.

Website Issues/Data Loss. At some point between the beta test and the beginning of statistical analysis of survey responses, several variables in both the incoming survey and outgoing survey were lost. It is unclear at this time whether a user error or a system failure caused this problem. Attempts to recover the information were unsuccessful. Some additional data analysis was planned but unable to be performed due to this loss of data.

3. What are current levels of awareness of high school students regarding Giant Hogweed and other environmental issues, and how will participation in this program affect the awareness of these topics?

A number of statistical methods were employed in an attempt to understand the background and breadth of knowledge of the beta test subjects regarding Giant Hogweed, the problem of invasive species, and of environmental problems in general. Perhaps more importantly, these processes were also designed to provide insight into whether participation in the program has had any impact on their environmental awareness. Following is the output of procedures conducted in SPSS based on the surveys taken by the high school students in the beta test (Appendices 1 & 2) and a summary of their analysis. It is important to understand that due to the small n, or sample size (16 for the Introductory Survey, 10 for the Outgoing Survey), most statistical tests conducted in this research do not have significant results, and the chi-square tests for the cross-tab analyses are invalid due to expected cell sizes of less than 5. However, while many analyses do not have sufficient sample size to show statistical significance, they do indicate trends, and future work can use increased sample sizes to test the significance of these trends. It also bears mentioning that the composition of the sample population is likely not representative of the student population of Latvia. The participants of the 2010 beta test were highly motivated students who voluntarily participated in a non-compulsive, science-based summer school enrichment program.

Key to Rank system, as seen in surveys in Appendices 1 & 2. The ranking system for the surveys is based on a low positive (1), high negative (5) ranking system. See below for precise descriptions of values.

1 = Very Important/Very Good

2 = Important/Good

3 = Neutral/Fair

4 = Not very Important/Poor

5 = Not at All/Very Poor

Statistical Analyses: Cross Tabulations

Cross tabulations were run on pairs of categorical variables from website surveys in order to test their association. Cross tabulations (Tables 1, 2, 7, 8, & 13) were taken from the Introductory Survey and provide some insight into the knowledge and experience of student participants prior to their participation in the program.

It should be noted here again that chi-square tests for significance of cross-tabs were not run due to insufficient sample size (all cross-tabs had at least one cell with an expected value of less than 5).

Statistical Analyses: Histograms and t-tests (Mann-Whitney)

Histograms are graphic representations of single variable analyses performed here to provide a side-by-side comparison of participant response before and after participation in the PPGIS program. Although there were different n values for the Introductory Survey (16) and Outgoing Survey (10), percentages of responses and changes in response percentages are discussed in each summary.

Mann-Whitney tests were performed to determine statistical significance of association between an ordinal variable and a binary categorical variable. In these analyses, the binary categorical variable reflected the *before* or *after* survey. The significance of the change in mean rank was tested for before vs. after participation in the program. Even in cases where significance was not achieved, these analyses summarized any change in mean rank of participant response to each variable. These changes in rank indicate best estimate of changes (positive or negative) in the environmental perception of participants.

Results (Table 1) indicate that most participants (13 out of 16) have known about Giant Hogweed for more than five years. Results also indicate that all (100%) participants who learned about Giant Hogweed from school or through media outlets have been aware of Giant Hogweed for more than five years, while a slightly smaller percentage (76.9%) of those that learned of Giant Hogweed from their parents or guardians have been aware of Giant Hogweed for more than five years. In addition, 15.4% of the participants (2 out of 16) have learned of Giant Hogweed only since learning of this project. This last percentage indicates that this PPGIS program has the potential to inform a small but substantial percentage of student participants of the dangers of Giant Hogweed.

Table 1

Cross tabulation Output for the survey variables "How long have you known about Giant Hogweed?" vs. "Where did you learn about Giant Hogweed?"

			How did you learn about Giant Hogweed?			Total
			From Parents/ Guardians	Media	School	
How long have you known Giant Hogweed is dangerous?	More Than 5 Years	Count	10	2	1	13
		Column %	76.9%	100.0%	100.0%	81.3%
	Since Project	Count	2	0	0	2
		Column %	15.4%	.0%	.0%	12.5%
	<1 Yr	Count	1	0	0	1
		Column %	7.7%	.0%	.0%	6.3%
Total		Count	13	2	1	16
		Column %	100.0%	100.0%	100.0%	100.0%

Results (Table 2) indicate that participants who have been injured or know someone who has been injured by Giant Hogweed are more likely to believe that their work on this research project will have an impact on the control and eradication of Giant Hogweed - 77.8% of responses, as compared with 42.9% of responses for those who have not been injured nor know someone who has been injured by Giant Hogweed. This result implies that participants that have more experience with Giant Hogweed feel more certain that working towards the control of Giant Hogweed will be productive. The potential for these individuals to provide landscape knowledge is high, and could be very useful when collecting data in their home areas.

Table 2

Cross tabulation Output for the survey variables "Have you or someone you know been injured by Giant Hogweed?" vs. "Do you think your work in this project will have an impact?"

			Injured?		Total
			No	Yes	
Impact?	Yes	Count	3	7	10
		Column %	42.9%	77.8%	62.5%
	Not Sure	Count	4	2	6
		Column	57.1%	22.2%	37.5%
Total		Count	7	9	16
		Column %	100.0%	100.0%	100.0%

Results (Figure 1) indicate that prior to participation in the program, 62.5% of respondents felt their work on this project would have an impact, while 37.5% felt unsure whether or not their work would have an impact. There were no responses for "no". Following participation, 40% of respondents felt their work on the project would have an impact, while 60% felt uncertain whether or not their work would have an impact. There were no responses for "no".

Mean rank of participant response to this question decreased (shifted toward participants feeling less confident their work on the project would have an impact) from 12.38 prior to participation to 15.30 after participation – a difference of 2.92 (Table 3). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .363 (Table 4) indicates a lack of significance, so the null hypothesis should be accepted.

These results indicate a significant shift to the negative (participants felt less confident that their work would have an impact) in responses after participation in the program. This is important, as it indicates that more should be done in the academic and training portions of the PPGIS programs to reinforce the value of individual participation. This also suggests that the research team may look for more ways to keep students involved in the project and in pursuing Giant Hogweed eradication goals upon their completion of data collection.

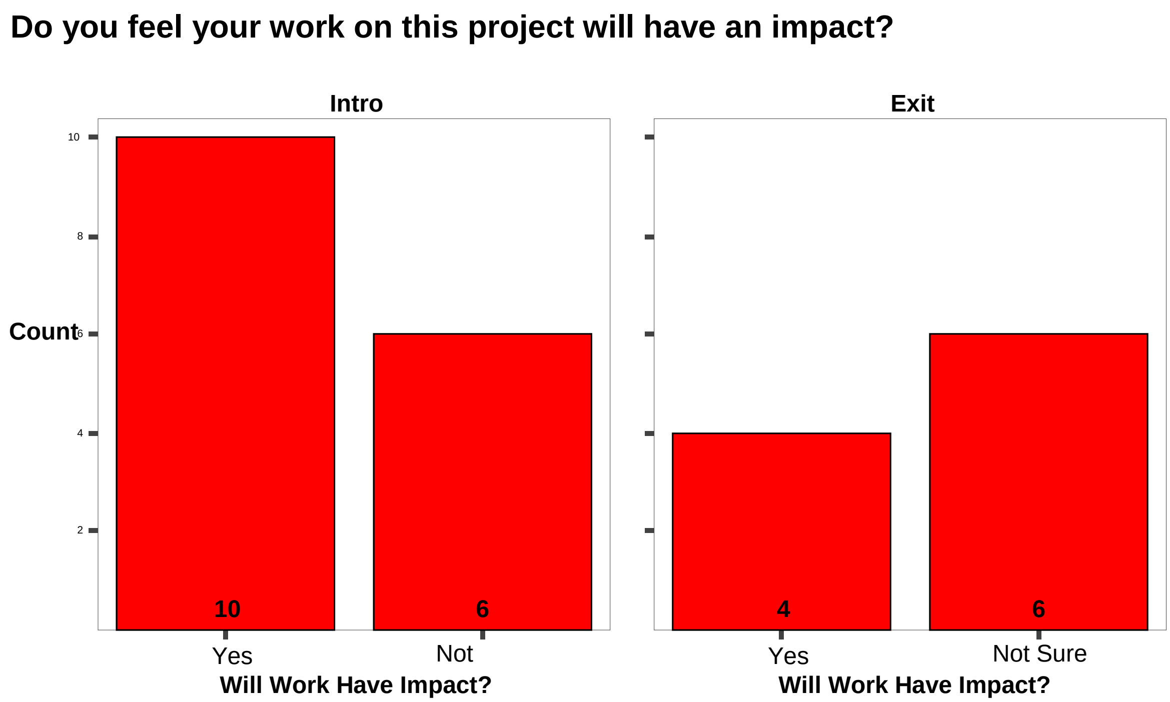

Figure 1
Histograms for variable "Do you think your work on this project will have an impact?" (Before & after participation)

Table 3
Mean rank output for variable "Do you feel your work in the project will have an impact?"

	Intro/Exit	N	Mean Rank
Do You Feel Your Work on This Project Will Have an Impact?	Intro	16	12.38
	Exit	10	15.30
	Total	26	

Table 4

Test statistics output for variable "Do you feel your work in the project will have an impact?"

	Project Impact
Mann-Whitney U	62.000
2-tailed p-value	.363

Results (Figure 2) indicate that before participating in this program 50% of participants thought they could "Always" identify Giant Hogweed, and 37.5% of participants thought they could "Usually" identify Giant Hogweed (87.5% combined). 6.25% thought they could identify Giant Hogweed "Sometimes", and another 6.25% thought they could identify it "Rarely". Results from the survey taken after participation in this program indicate that participants felt they were now able to "Always" identify Giant Hogweed 60% of the time and "Usually" identify Giant Hogweed 40% of the time (100% total). There were no responses in the outgoing survey for participants being able to identify Giant Hogweed "Sometimes", "Rarely", or "Never". These results indicate that participants were more likely to feel they could positively identify Giant Hogweed after participation in the program than they were prior to participation. This knowledge will help in the data collection process, and may prevent injuries in the long run.

Mean rank of participant response to this question increased (shifted towards participants feeling more confident about identifying Giant Hogweed) from 14.25 prior to participation to 12.30 after participation – a difference of 1.95 (Table 5). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .551 (Table 6) indicates that while the trend is towards feeling more able to identify Giant Hogweed after participation in the program, there is a lack of statistical significance.

How easily can you identify Giant Hogweed?

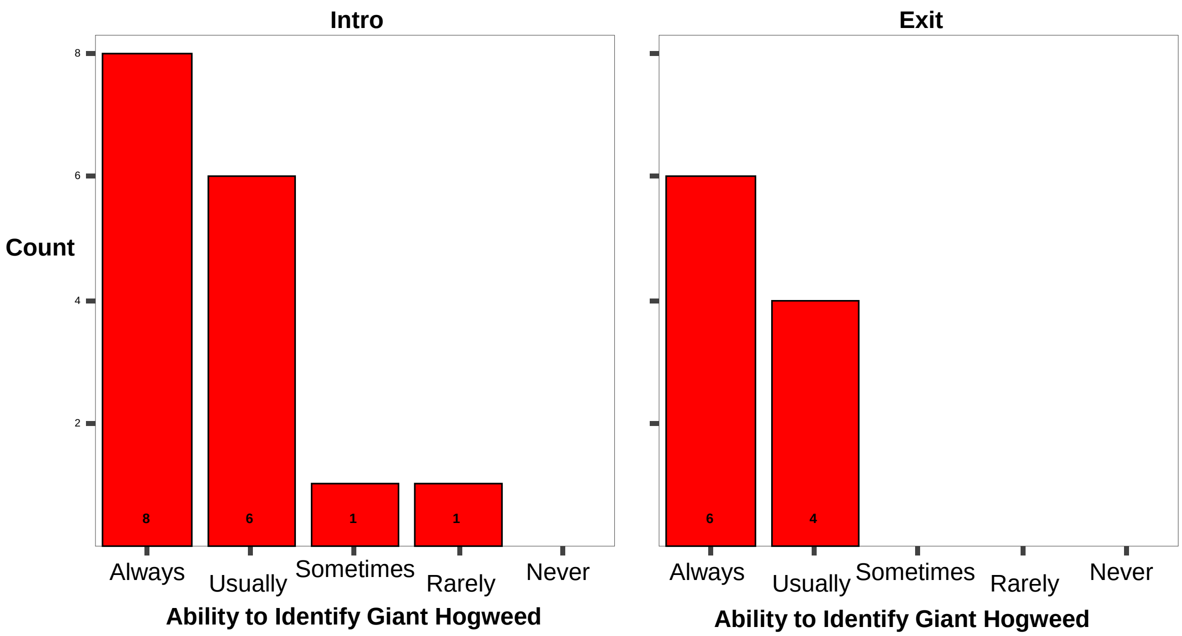

Figure 2
Histograms for the variable "How easily can you identify Giant Hogweed?" (Before & after participation)

Table 5
Mean rank output for variable "How easily can you identify Giant Hogweed?"

	Intro/Exit	*N*	*Mean Rank*
Hogweed Identification	Intro	16	14.25
	Exit	10	12.30
	Total	26	

Table 6
Test statistics output for variable "How easily can you identify Giant Hogweed?"

Hogweed Identification	
Mann-Whitney U	68.000
2-tailed p-value	.551

Results (Table 7) indicate that participants that live on a farm or near a park are more likely to have been injured or know someone that has been injured through contact with Giant Hogweed – 70% of responses. Conversely, 83.3% of respondents who reported not living on a farm or near a park also responded that they knew no one who had been injured by Giant Hogweed. These results indicate that individuals on farms or near parks are more likely to have had experiences with Giant Hogweed.

Table 7
Cross tabulation output for variables "Do you know someone who has been injured by Giant Hogweed?" vs. "Do you live near a farm?"

			Do you live on a farm/near a park?		
			No	Yes	Total
Do you know someone who has been injured by Giant Hogweed?	No	Count	5	3	8
		Column %	83.3%	30.0%	50.0%
	Yes	Count	1	7	8
		Column %	16.7%	70.0%	50.0%
Total		Count	6	10	16
		Column %	100.0%	100.0%	100.0%

Results (Table 8) indicate that 50% of respondents that live on a farm or near a park feel that invasive species is a very important issue. Participants who do not live on a farm or near a park were equally divided (33.3% each) between feeling that invasive species was very important, important, and neutral. As hypothesized, this implies that participants that are more exposed to the natural landscape (non-urban inhabitants) believe that invasive species is an important issue and a threat to the environment.

Table 8

Cross tabulation output for variables "How important is the issue of invasive species to you?" vs. "Do you live on a farm/near a park?"

			Do you live on a farm/near a park?		Total
			No	Yes	
How important is the issue of invasive species to you?	Very Important	Count	2	5	
		Column %	33.3%	50.0%	43.8%
	Important	Count	2	4	6
		Column %	33.3%	40.0%	37.5%
	Neutral	Count	2	1	3
		Column %	33.3%	10.0%	18.8%
Total		Count	6	10	16
		Column %	100.0%	100.0%	100.0%

Results (Figure 3) indicate that prior to participation in this program, 43.75% of respondents felt the issue of invasive species was very important, while 37.5% felt is was important, and 18.75% felt neutrally about the issue. There were no responses for "not very important" or "not at all". After participation, 80% of respondents felt the issue of invasive species was very important, while 20% felt it was important. This result marks a dramatic shift to the positive (the issue became more important) in the perception of the importance of the issue of invasive species in respondents. As hypothesized, participation in the PPGIS program has increased the importance of environmental issues in respondents.

Mean rank of participant response to this question increased (shifted toward feeling invasive species is a more important issue) from 15.5 prior to participation to 10.3 after participation – a difference of 5.2 (Table 9). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .097 (Table 10) is close to significant at the .05 level.

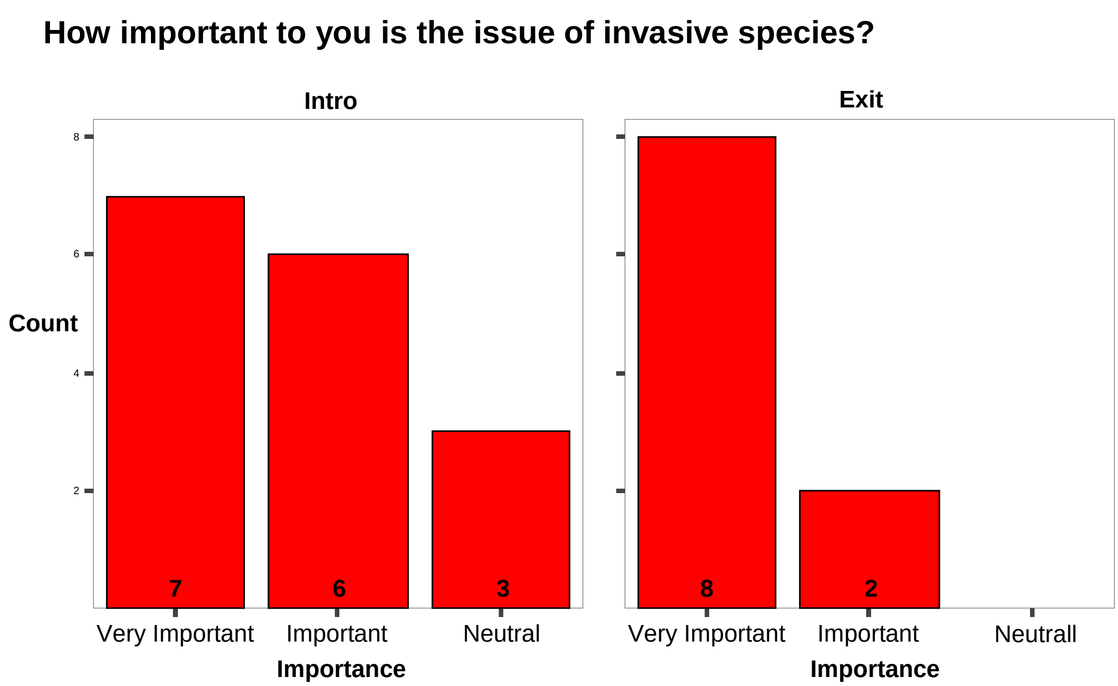

Figure 3
Histograms for the variable "How important to you is the issue of invasive species?" (Before & after participation)

Table 9

Mean rank output for variable "How important is the issue of invasive species to you?"

	Intro/Exit	N	Mean Rank
How important is the issue of invasive species to you?	Intro	16	15.50
	Exit	10	10.30
	Total	26	

Table 10

Test statistics output for variable "How important is the issue of invasive species to you?"

	How important is the issue of invasive species to you?
Mann-Whitney U	48.000
2-tailed p-value	.097

Results (Table 11) indicate that before participation there is quite a high positive correlation (.524 coefficient) between participant responses for the importance of the issue of invasive species and the importance of eliminating Giant Hogweed in Latvia. The p-value of .037 indicates significant result, allowing us to conclude a positive relationship between these two variables.

Table 11

Correlation Output for variables "How important is the issue of invasive species to you?" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?" before participation in the program

Before participation			How important is it to you that Giant Hogweed be eliminated from Latvia?	How important is the issue of invasive species to you?
Spearman's rho	How Important is it to you that Giant Hogweed be Eliminated from Latvia?	Correlation Coefficient	1.000	.524
		p-value	.	.037
		N	16	16
	How important is the issue of invasive species to you?	Correlation Coefficient	.524	1.000
		p-value	.037	.
		N	16	16

Results (Table 12) indicate that after participation there is a negative correlation (-.327 coefficient) between participant responses for the importance of the issue of invasive species and the importance of eliminating Giant Hogweed in Latvia (not significant: p-value = .356). Though there was a lack of significance, the Spearman's correlation coefficient was much more negative (difference of .851) after participation. This is an unexpected result, as lecture materials included in the academic program are designed to illustrate to students the negative environmental effects of invasive species in Latvia. The hypothesis for the relationship between these two variables (increase in correlation after participation) was incorrect.

Table 12

Correlation Output for variables "How important is the issue of invasive species to you?" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?" after participation in the program.

After participation			How important is it to you that Giant Hogweed be eliminated from Latvia?	How important is the issue of invasive species to you?
Spearman's rho	How important is it to you that Giant Hogweed be eliminated from Latvia?	Correlation Coefficient	1.000	-.327
		p-value	.	.356
		N	10	10
	How Important is the issue of invasive species to you?	Correlation Coefficient	-.327	1.000
		p-value	.356	.
		N	10	10

Results (Table 13) indicate that participants who have been injured or know someone who has been injured by Giant Hogweed have not necessarily had experience attempting to control or destroy it. Of those that have been injured or know someone who has been injured, 44.4% (less than half) responded that they know someone who has had difficulty controlling Giant Hogweed. This is interesting as it implies that a considerable percentage of injuries incurred from exposure to Giant Hogweed do not result from deliberate contact with the weed.

Table 13

Cross tabulation Output for variables "Have you or someone you know been injured by Giant Hogweed?" vs. "Do you know anyone who has had difficulty in controlling Giant Hogweed?"

			Injured?		
			No	Yes	Total
Difficulty controlling Giant Hogweed?	No	Count	6	5	11
		Column %	85.7%	55.6%	68.8%
	Yes	Count	1	4	5
		Column %	14.3%	44.4%	31.3%
Total		Count	7	9	16
		Column %	100.0%	100.0%	100.0%

Results (Figure 4) indicate that 43.75% of participants considered environmental issues to be "Very Important", and 43.75% of participants considered environmental issues to be "Important" prior to participation in the program (87.5% total). 6.25% of participants had either a "Neutral" opinion on environmental issues or felt that environmental issues were "Not Very Important". There were no responses for "Not At All". After participation, 70% of participants indicated that they felt environmental issues were "Very Important", while 30% felt that environmental issues were "Important" (100% total). There were no responses for "Neutral", "Not Very Important" or "Not At All". As hypothesized, these results indicate that environmental issues became of greater importance to respondents after participating in the program.

Mean rank of participant response to this question increased (shifted towards a feeling of greater importance of environmental issues) from 15.00 prior to participation to 11.10 after participation - a difference of 3.90 (Table 14). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .220 (Table 15) indicates a lack of significance, so the null hypothesis should be accepted.

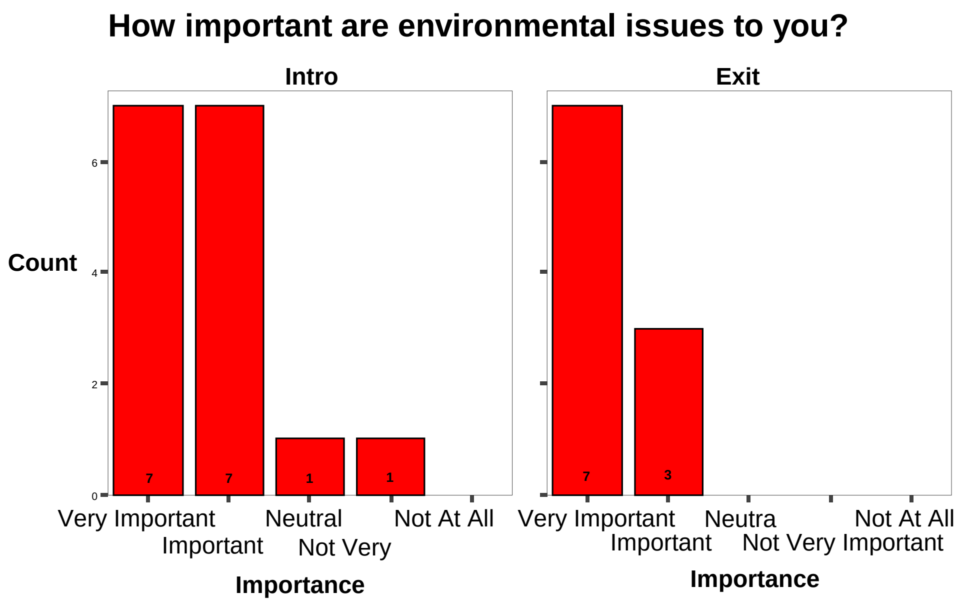

Figure 4
Histograms for the variable "How important are environmental issues to you?" (Before & after participation)

Table 14
Mean rank output for variable "How important are environmental issues to you?"

	Intro/Exit	N	Mean Rank
How important are environmental issues to you?	Intro	16	15.00
	Exit	10	11.10
	Total	26	

Table 15

Test statistics output for variable "How important are environmental issues to you?"

	How important are environmental issues to you?
Mann-Whitney U	56.000
2-tailed p-value	.220

Results (Figure 5) indicate that before participation in this program, 56.25% of respondents felt it was very important to eliminate Giant Hogweed in Latvia, while 31.25% felt it was important, and 12.5% felt neutrally about the issue. There were no responses for "not very important", and "not at all". After participation, 70% of respondents felt that it was very important to eliminate Giant Hogweed from Latvia, and 30% felt it was important. There were no responses for "neutral", "not very important", or "not al all". These results indicate that there was a moderate shift to the positive (the issue became more important) in response after participation in the program. As hypothesized, respondents felt that it was more important that Giant Hogweed be eliminated from the Latvian landscape after having participated in the program.

Mean rank of participant response to this question increased (shifted toward participants feeling that it is more important that Giant Hogweed be eliminated) from 14.38 prior to participation to 12.10 after participation – a difference of 2.28 (Table 16). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .484 (Table 17) indicates a lack of significance, so the null hypothesis should be accepted.

How important to you is it that Giant Hogweed be eliminated from Latvia?

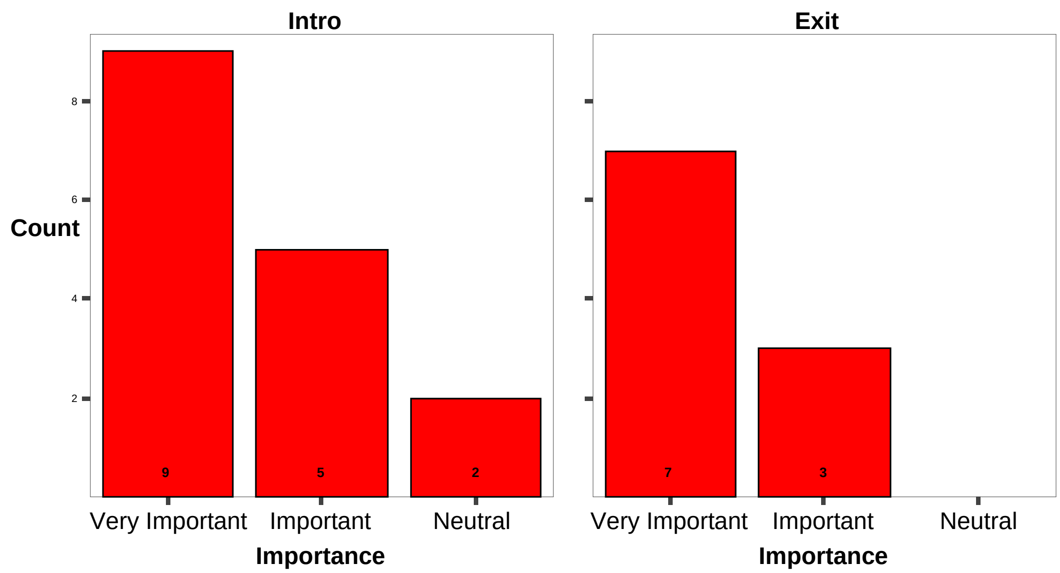

Figure 5
Histograms for the variable "How important is it to you that Giant Hogweed be eliminated from Latvia?" (Before & after participation)

Table 16
Mean rank output for variable "How important is it to you that Giant Hogweed be eliminated from Latvia?"

	Intro/Exit	N	Mean Rank
How important is it to you that Giant Hogweed be eliminated from Latvia?	Intro	16	14.38
	Exit	10	12.10
	Total	26	

Table 17
Test statistics output for variable "How important is it to you that Giant Hogweed be eliminated from Latvia?"

	How important is it to you that Giant Hogweed be eliminated from Latvia?
Mann-Whitney U	66.000
2-tailed p-value	.484

In the following analysis, 2 correlations were conducted to understand the *change* in relationship (from before to after participation in the program) between variables.

Results (Table 18) indicate that before participation there is a slightly positive correlation (.076 coefficient) between participant responses for the importance of environmental issues and the importance of eliminating Giant Hogweed in Latvia. The p-value of .780 indicates a lack of significance, so the null hypothesis (no correlation) should be accepted.

Table 18
Correlation output for variables "How important are environmental issues to you?" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?" (Before participation).

Before participation			How important are environmental issues to you?	How important is it to you that Giant Hogweed be eliminated from Latvia?
Spearman's rho	How important are environmental issues to you?	Correlation Coefficient	1.000	.076
		Sig. (2-tailed)	.	.780
		N	16	16
	How important is it to you that Giant Hogweed be eliminated from Latvia?	Correlation Coefficient	.076	1.000
		p-value	.780	.
		N	16	16

Results (Table 19) indicate that after participation there is a slightly positive correlation (.076 coefficient before participation and 048 coefficient after participation) between participant responses for the importance of environmental issues and the importance of eliminating Giant Hogweed in Latvia (not significant: p-value = .896). Though there was a lack of significance, the Spearman's correlation coefficient was slightly more negative (difference of .028) after participation. This analysis shows that the correlation between the importance of Giant Hogweed being eliminated and the important of environmental issues decreased. This could be due to the fact that the general trend that after participation students was to feel stronger about eliminating Giant Hogweed.

Table 19

Correlation output for variables "How important are environmental issues to you?" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?" (After participation)

After participation			How important are environmental issues to you?	How important is it to you that Giant Hogweed be eliminated from Latvia?
Spearman's rho	How Important are environmental Issues to you?	Correlation Coefficient	1.000	.048
		p-value	.	.896
		N	10	10
	How important is it to you that Giant Hogweed be eliminated from Latvia?	Correlation Coefficient	.048	1.000
		p-value	.896	.
		N	10	10

Results (Figure 6) indicate that 68.75% of participants considered the health of the environment in Latvia to be "Good" prior to participation in the program. There were no responses for "Very Good". 25% of participants considered the environmental health of Latvia to be "Fair", while 6.25% considered it to be "Poor" ("Fair" and "Poor" combined comprised 31.25% of total). There were no responses for "Very Poor". After participation, 70% of participants indicated that they felt the health of the environment in Latvia was "Good", while 30% felt that the environment in Latvia is in "Fair" health. There were no responses for "Very Good", "Poor", or "Very Poor". As hypothesized, these results indicate a shift to the positive in the perception of environmental quality in the home country of participants. However, the shift is only marginal.

Mean rank of participant response to this question increased (shifted toward rating the Latvian environment healthier) from 13.66 prior to participation to 13.25 after participation – a difference of .41 (Table 20). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .897 (Table 21) indicates a lack of significance, so the null hypothesis should be accepted.

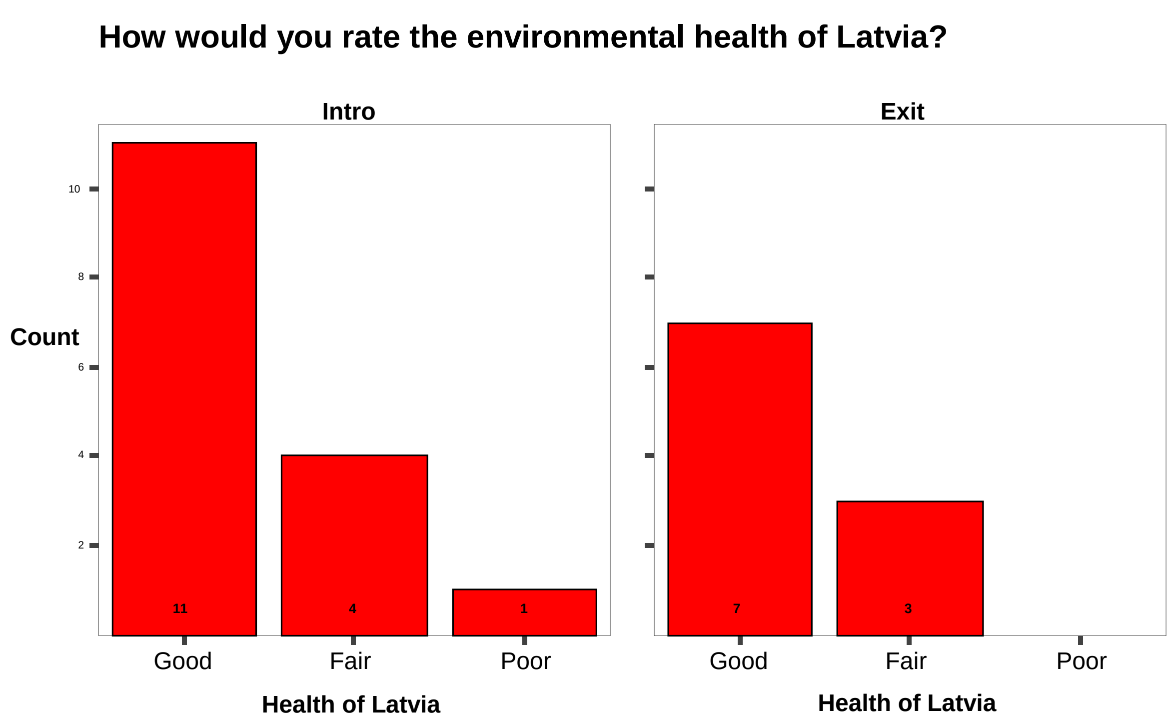

Figure 6
Histograms for the variable "How would you rate the environmental health of Latvia?" (Before & after participation

Table 20

Mean rank output for variable "How would you rate the environmental health of Latvia?"

	Intro/Exit	N	Mean Rank
How would you rate the environmental health of Latvia?	Intro	16	13.66
	Exit	10	13.25
	Total	26	

Table 21

Test statistics output for variable "How would you rate the environmental health of Latvia?"

	How would you rate the environmental health of Latvia?
Mann-Whitney U	77.500
2-tailed p-value	.897

Results (Figure 7) indicate that 6.25% of participants considered the health of the global environment to be "Good" prior to participation in the program. There were no responses for "Very Good". 43.75% of participants considered the environmental health of the globe to be "Fair" and "Poor". 6.25% considered it to be "Very Poor". After participation, 10% of participants indicated that they felt the health of the global environment was "Good". 40% felt that the global environment is in "Fair" health, while 50% felt it is "Poor". There were no responses for "Very Good", or "Very Poor". These results indicate that participants felt the environmental health of the globe is marginal both before and after participation, and that the PPGIS program has had little effect on their feelings on global environmental health.

Mean rank of participant response to this question increased (shifted toward rating the global environment healthier) from 13.75 prior to participation to 13.10 after participation – a difference of .65 (Table 22). Running a Mann-Whitney test for significance in difference of mean rank between two groups, the p-value of .856 (Table 23) indicates a lack of significance, so the null hypothesis should be accepted.

How would you rate the environmental health of the globe?

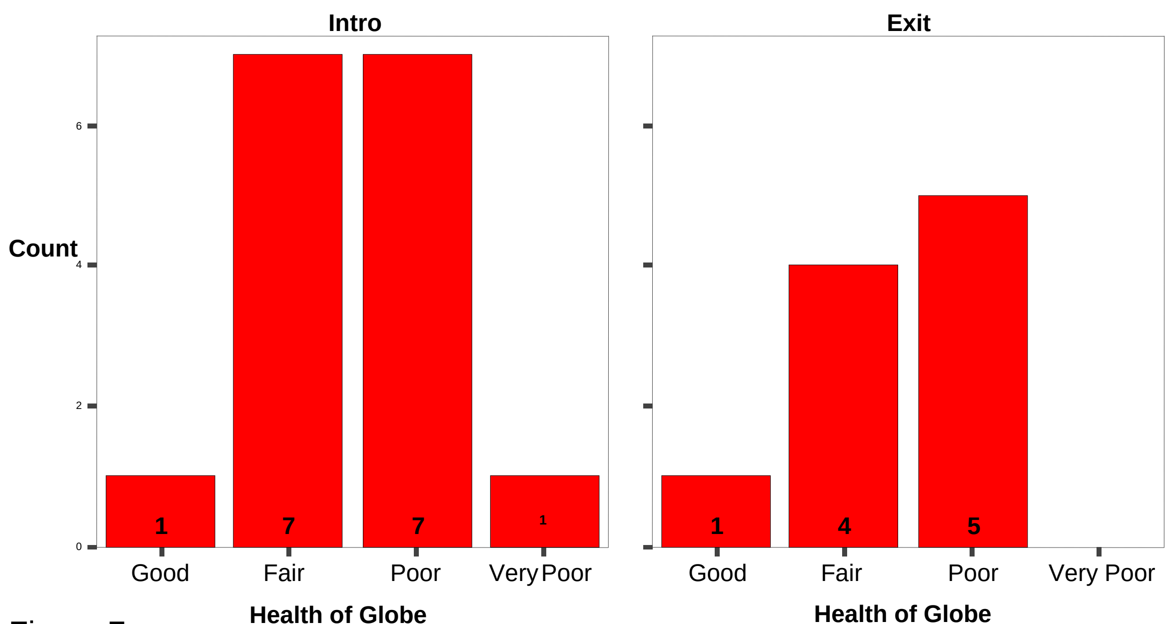

Figure 7
Histograms for the variable "How would you rate the environmental health of the globe?" (Before & after participation)

Table 22

Mean rank output for variable "How would you rate the environmental health of the globe?"

	Intro/Exit	N	Mean Rank
How would you rate the environmental health of the globe?	Intro	16	13.75
	Exit	10	13.10
	Total	26	

Table 23

Test statistics output for variable "How would you rate the environmental health of the globe?"

	How would you rate the environmental health of the globe?
Mann-Whitney U	76.000
2-tailed p-value	.856

In the following analysis, 2 correlations were conducted to understand the *change* in relationship (from before to after participation in the program) between the variables, "How would you rate the environmental health of Latvia" and "How important is it to you that Giant Hogweed be eliminated from Latvia?"

Results (Table 24) indicate that before participation there is a positive correlation (.284 coefficient) between participant responses for their rating of the health of the Latvian environment species and the importance of eliminating Giant Hogweed in Latvia. The p-value of .286 indicates a lack of significance, so the null hypothesis (no correlation) should be accepted.

Table 24

Correlation output for variables "How would you rate the environmental health of Latvia" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?"

Before participation			Important that Giant Hogweed be eliminated	Environmental health of Latvia
Spearman's rho	Important that Giant Hogweed be eliminated	Correlation Coefficient	1.000	.284
		p-value	.	.286
		N	16	16
	Environmental health of Latvia	Correlation Coefficient	.284	1.000
		p-value	.286	.
		N	16	16

Results (Table 25) indicate that after participation there is a slightly positive correlation (.048 coefficient) between participant responses for the rating of the environmental health of Latvia and the importance of eliminating Giant Hogweed in Latvia (not significant: p-value = .896). Though there was a lack of significance, the Spearman's correlation coefficient was more negative (difference of .236) after participation. This result implies that the correlation between the thoughts of participants on these issues decreased after participation. This may be due to the fact that a general increase has occurred in valuing Giant Hogweed elimination after participation.

Table 25

Correlation output for variables "How would you rate the environmental health of Latvia" vs. "How important is it to you that Giant Hogweed be eliminated from Latvia?"

After participation			Important that Giant Hogweed be eliminated	Environmental health of Latvia
Spearman's rho	Important that Giant Hogweed be eliminated	Correlation Coefficient	1.000	.048
		p-value	.	.896
		N	10	10
	Environmental health of Latvia	Correlation Coefficient	.048	1.000
		p-value	.896	.
		N	10	10

4. Based on the collected PPGIS data accuracy, what specific methods can be used to integrate data obtained from the PPGIS project involving Latvian high school students and other interested parties with data obtained from remote sensing/satellite imagery for locating Giant Hogweed?

Precise locations for two of the known points of Giant Hogweed collected by the research team were then identified through aerial photography in Google maps:

Researcher Point A (Roadside) – N 57.51059, E 25.43342

Researcher Point B (Roadside) – N 57.51016, E 25.44328

These points represent roadside locations adjacent to patches of Giant Hogweed. Relative to these positions, the center of each patch of Giant Hogweed was determined with the aid of Google Maps:

Researcher Patch Center A – N 57.51028, E 25.44328

Researcher Patch Center B – N 57.51005, E 25.43806

Two points obtained from PPGIS participants for the same two Giant Hogweed locations were selected:

Participant Point A (Roadside) – N 57.51017, E 25.4433

Participant Point B (Roadside) – N 57.51015, E 25.4379

The latitude and longitude for the two points, Participant Point A (Roadside) and Participant Point B (Roadside), were combined with their respective bearing and distance information in Microsoft Excel. A formula - created by Dr. Taff - uses these four pieces of information (latitude, longitude, bearing and distance) to determine latitude and longitude for the center of each patch of Giant Hogweed as estimated by PPGIS participants. The resulting latitude and longitude are highlighted in Table 26.

Table 26
Participant estimated Giant Hogweed locations.

Point ID	Latitude (Roadside)	Longitude (Roadside)	Bearing	Distance (meters)	Latitude (Center of Patch)	Longitude (Center of Patch)
Participant Point A	57.51017	25.4433	130	15	57.51027	25.44314
Participant Point B	57.51015	25.4379	185	3	57.51014	25.43785

With these steps accomplished, the center of Giant Hogweed patches A and B as designated by the research team can be compared for accuracy of latitude and longitude as reported by PPGIS participants. Differences in decimal degrees were converted to distance in meters to better display the relationships between both sets of points. Mathematical results are indicated in Table 27.

Table 27

Distance discrepancies for participant estimated Giant Hogweed locations vs. researcher determined Giant Hogweed locations.

	Giant Hogweed Patch A		Giant Hogweed Patch B	
	Latitude	Longitude	Latitude	Longitude
Researcher Point Data	57.51028	25.44328	57.51005	25.43806
Participant Point Data	57.51027	25.44314	57.51014	25.43785
Difference in Decimal Degrees	.00001	.00014	-.00009	.00021
Difference in Meters	1.1	15.4	-9.9	23.1

In order to determine the absolute distance error from the actual center of the patch (as determined by the author) to the participant's estimates for both Giant Hogweed Patch A, and Giant Hogweed Patch B, the following distance formula was applied:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Here, d = distance, x_2 = participant estimated longitude, x_1 = actual longitude of center of Giant Hogweed patch, y_2 = participant estimated latitude, and y_1 = actual latitude of center of Giant Hogweed patch. The following absolute distance results were found:

Hogweed Patch A: 15.4 meters

Hogweed Patch B: 25.52 meters

Based on the orientation of the roadside points relative to the center of the Giant Hogweed patches, it was determined that the key problem the students had was in the determination of the correct bearing – these estimates tended to be somewhat inaccurate. The final point estimates, however, were close enough patch of Giant Hogweed that the research team would be able to identify the perimeter of the patch when attention is given to one point at a time either on the ground or in aerial photos.

The hazardous nature of Giant Hogweed makes it intrinsically difficult to collect accurate spatial data. Were there no human health risk, students could walk into the patch and more easily indentify their estimate of the patch center by simply standing in it. This would eliminate the need for distance and bearing estimates. Compounding the issue is morphology of Giant Hogweed. Participants are forced to look through five meter tall, densely-leaved plants growing in a countryside with very little relief in order to attempt to report their estimates.

Results indicate that data collected in the field by Latvian high school students would likely be useful in the creation of an inventory of Giant Hogweed locations in Latvia. These data will also effectively serve as a ground verification tool during the satellite image classification process, and in the process of developing maps and models, however these results show that the data cannot be used without verification by the research team. This may represent substantial challenges if the project is implemented on a countrywide scale, as verifying each point individually may be overly cumbersome.

Conclusion

The beta test conducted at Vidzeme University in Valmiera, Latvia during August of 2010 supports the effectiveness of using the web-based PPGIS framework developed in this research for the purpose of inventorying and monitoring Giant Hogweed in Latvia (Research Question 1a). The website functions as a tool capable of communicating the goals and purpose of this research, and the role of participants within it. It also provides educational materials to those participants, and is an effective means of collecting and storing point data to be used in GIS/remote sensing analyses to monitor and model the spread of the weed. No obstacles in the flow of participation due to problems in the structure of the program were encountered or reported during or after the test period. To date, 44 Giant Hogweed locations from three separate regions of Latvia have been uploaded, displayed and stored on the website.

Statistical analysis performed on participant responses indicate that the educational component of the program has been impactful in providing participants with information regarding the environmental problems that effect their country, and has sensitized them to critical issues (Research Questions 1a, 3). Increases in mean rank of participant responses to questions assessing environmental awareness were seen in six survey questions, ranging in value from .41 to 5.2, on the 5-point ordinal scale discussed in the **Results** section above. The greatest increase was found in the variable “How important is the issue if invasive species to you?” This is an encouraging result, as it indicates that the seriousness of the issue is being appropriately stressed in the academic portion of the program, and that participants are receiving the message. In only one variable did mean rank decrease (-2.92), “Do you feel your work on this project will have an impact?” as seen in Table 4. These findings suggest that although environmental awareness appears to have increased in participants, more could possibly be done during the educational component to help participants understand more clearly how valuable their contributions are to the project. Regarding this issue, studies have indicated that the increase in awareness that participants gain by becoming involved in scientific research may lead to a decrease in their feelings regarding the value of their efforts in having a positive impact on environmental problems (Rowe, 2004). This may account for the decrease in confidence in the participants of the 2010 beta test.

To date, tested methods have not proven effective as a means for increasing participation in the program developed in this research (Research Question 2a). This “bottom up” approach of using beta test participants as ambassadors to help incorporate the program into science curriculum at Latvian high schools has yielded no results, and only a small amount of additional data. The program has yet to be taught at any schools independent of the research team’s direct involvement. Plans are in progress to convene a workshop aimed at instructing Latvian high school teachers about project protocol and communicating with them directly in an attempt to increase the scale of the program. Working directly with the Latvian Geography Teachers Association to encourage participation is also a consideration. Creating some type of incentive program, wherein something is “in it” for those who participate, may encourage more involvement as well.

Excluding the difficulty in finding an effective means of increasing participation in the PPGIS program, relatively few problems have been experienced in the process of implementing this program (Research Question

2b). The small sample size of the data (survey responses) collected due to low participation rates in this summer program resulted in the technical invalidation of statistical analysis results. However, further study and additional analyses are planned. Moving forward, a respondent ID variable will be added to the required responses in each survey so more in-depth and individual-level analysis may be performed. A small number of responses to certain variables were lost at some point between the end of the beta test and the beginning of the data analysis. It is unclear whether this data loss occurred as a result of human error, or from a system failure of some type. Several inquiries to Google^{tm} technical support have met with no response.

The distance from the site has made logistical issues more difficult, but not impossible. The "out of sight, out of mind" effect may have contributed to the lack of participation following the beta test. Language issues have hampered communication between the research team and Latvian high school teachers, but the true value of this effect is difficult to calculate.

The accuracy assessment performed on data collected by beta test participants indicates that the quality of the data is sufficient for use as ground verification of Giant Hogweed locations (Research Question 4). The collected data can be used to locate and determine the extent of Giant Hogweed present in the area of the point data collection. It can be used for image classification only when the research team analyzes each data point individually in high-resolution aerial photos. However, the data can be used without such analyses for Giant

Hogweed spread modeling, since precise locations are less important for that purpose.

In addition, accuracy assessment of the magnitude of errors (in meters) between the point data collected by participants and the true point locations indicates that more detailed instruction may be required on the webpage located on the project website called “Using a Compass to Take a Bearing” as these measurements suffered from a greater degree of inaccuracy. Additional accuracy assessments should be performed at interval as the project moves forward to insure that data quality levels are maintained.

Further Study

Development of this web-based participatory GIS program continues into the summer months of 2011. A second training session will take place in Valmiera, Latvia, in which a new group of high school students will participate in the program at the 2011 Baltic International Summer School (BISS). Attempts will be made to acquire new locations of Giant Hogweed locations, which will serve as training sites and add new data to the inventory. This situation will also offer a second attempt to capitalize on the potential for these students to act as ambassadors, bringing the program and their knowledge back with them to their home schools. While in situ, the research team will continue to acquire additional ground truth and ground control points. The potential also exists to perform verification of the point data collected by beta test participants since the end of summer 2010.

The loss of data (participant responses) at some point between their collection and the beginning of statistical analysis brought about a need to reassess the number and type of analyses that could be performed. In this effort, it became clear that some of the original variables overlapped, and that the same amount of information could be extracted from fewer questions. In the second round of testing, these redundant variables will be omitted. In addition, the author feels that the phrasing of the variable “Do you feel that your work on this project will have an impact?”, may be too vague. A more direct - and therefore more easily understood – version of this variable will be included in the next round of surveys.

Plans are also in motion to arrange a training workshop during summer 2011 in which geography teachers from throughout Latvia will be convened with the intention of their training on PPGIS project protocol, and instruction on how the program can be integrated into their curriculum. The dates and specifications of this event have yet to be confirmed at the time of this writing.

In addition, the author has been awarded a grant by the U.S. Fulbright Commission with aims at continuing the forward progress of the agenda of The Giant Hogweed Project. The term of the award will extend throughout the academic year of 2011 – 2012. Time and energy will be spent primarily on networking with schools throughout Latvia in an attempt to further increase participation in the PPGIS program.

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Appendices

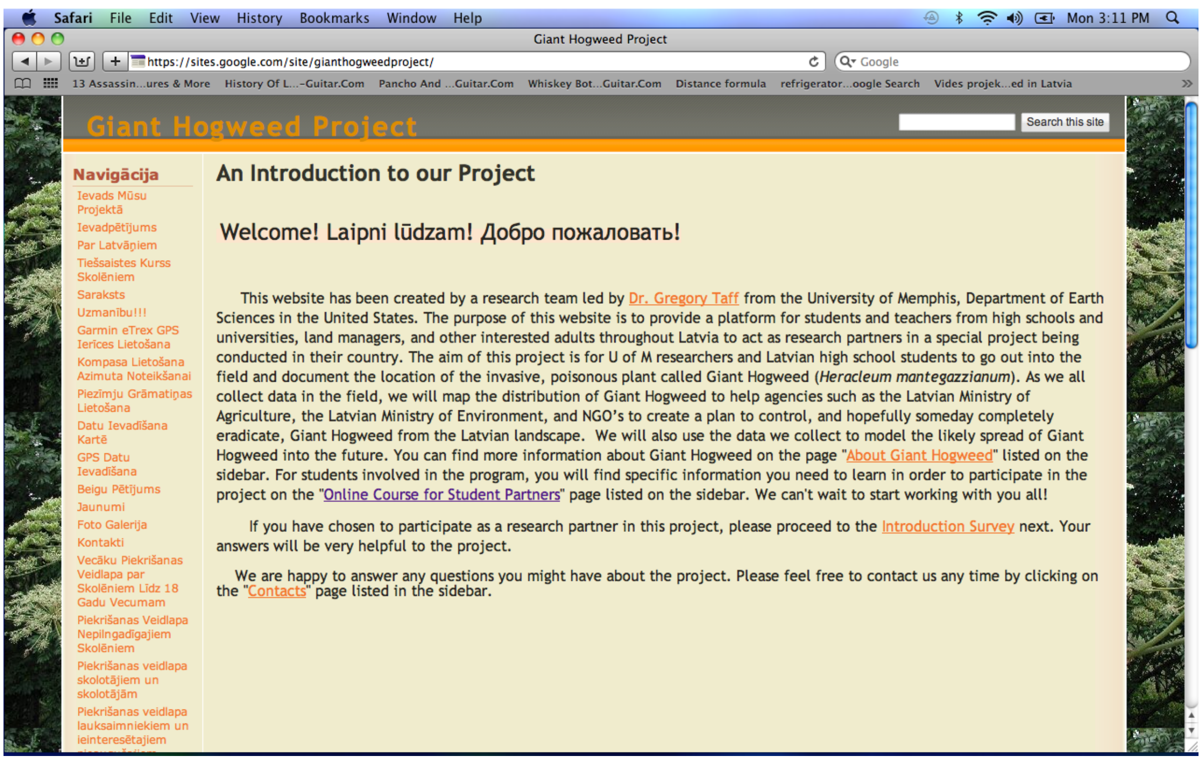
Appendix A: Introductory Survey Questions

1. Do you live on a farm/near a park?
2. How easily can you identify Giant Hogweed?
3. How long have you been aware of the presence of Giant Hogweed in your area (in your neighborhood or near your school)?
4, How long have you been aware of the presence of Giant Hogweed in Latvia?
5. How did you learn about Giant Hogweed?
6. How long have you known Giant Hogweed is dangerous?
7. Have you or anyone close to you had difficulty in controlling invasive Giant Hogweed on your property?
8. Have you or anyone you know been injured through contact with Giant Hogweed
9. How important is it to you that Giant Hogweed be eliminated from Latvia?
10. Which do you think are good ways to eliminate Giant Hogweed? (Please check all that apply)
11. What do you think are the three (3) greatest dangers to the environment in your country?
12. What do you think are the three (3) greatest danger to the global environment?
13. How important are environmental issues to you?
14. How important is the issue of invasive species to the environment in Latvia?
15. How would you rate the health of the environment in Latvia
16. How would you rate the health of the global environment?
17. Do you think your work on this project will have an impact on the environment?

Appendix B: Outgoing Survey Questions

1. How easily can you identify Giant Hogweed?
2. How important is it to you that Giant Hogweed be eliminated from Latvia?
3. Which do you think are good ways to eliminate Giant Hogweed?
4. What do you think are the three (3) greatest dangers to the environment in your country?
5. How important are environmental issues to you?
6. How important in the issue of invasive species to the environment in Latvia?
7. How would you rate the health of the environment in Latvia?

Appendix C: Homepage of the Giant Hogweed Project Website



sites.google/site/gianthogweedproject

Appendix D: Division of labor among the members of the Giant Hogweed Project

Giant Hogweed Project

Elements

Literature Review (Giant Hogweed, PPGIS)
Develop Website
Develop PPGIS Protocol
Create Surveys
Develop Instructions for Teachers
Create Project Map
Develop Academic Training Modules
Beta Test PPGIS Project
Collect Ground Truth/Ground Control Data
Maintain Communication With Participants
Incorporate Collected Data into Inventory
Create Models for Spread of Giant Hogweed
Satellite Image Classification

Division of Labor
Orange = Research Team
Red = Mike Larrivee
Blue = Simon Fonji
Green = Rebecca Almond
* All elements of the Giant Hogweed Project are overseen by the project PI, Dr. Gregory N. Taff